328 AMAZING IMAGES & CUTAWAYS INSIDE

THE MAGAZINE THAT FEEDS MINDS

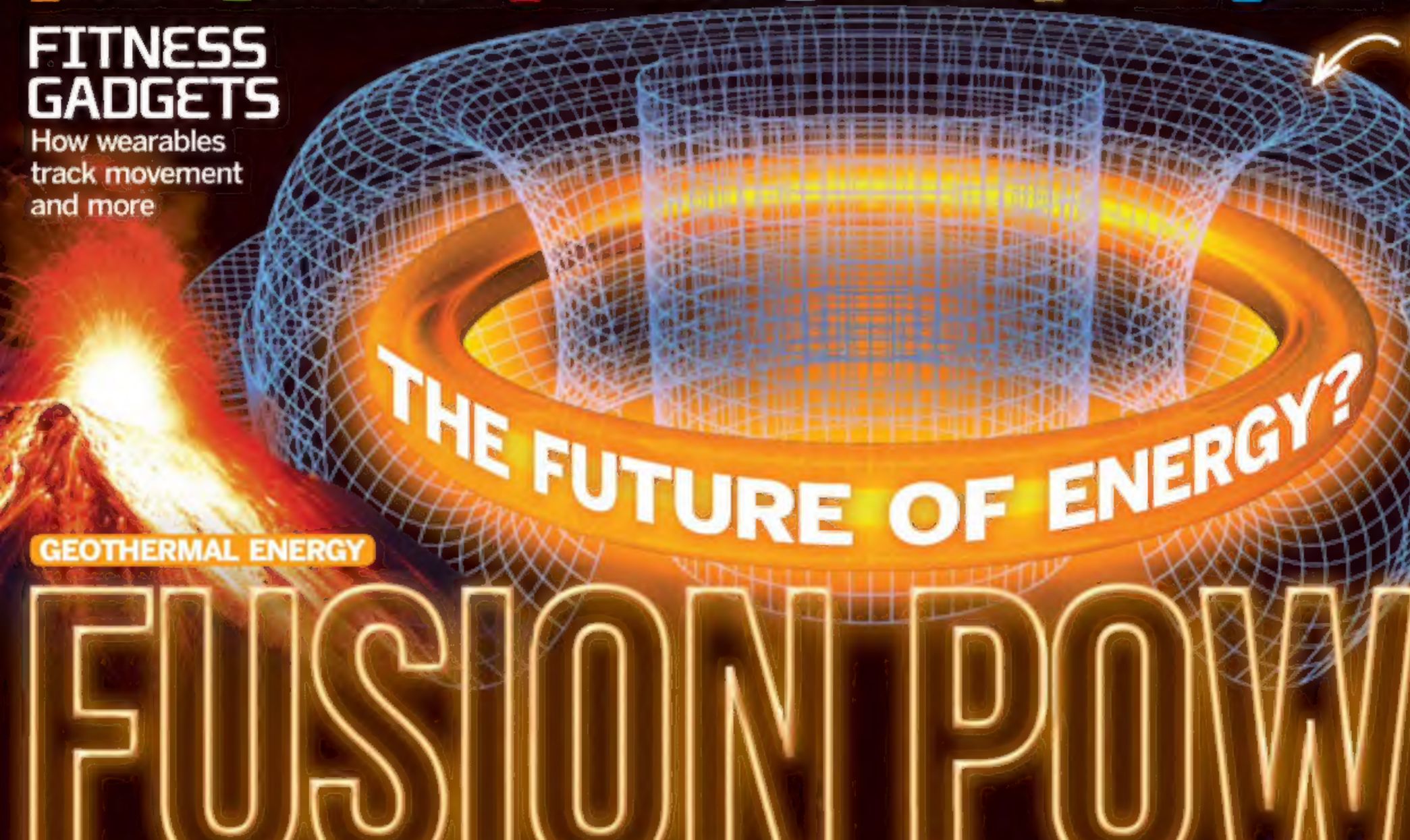
HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE

SCIENCE OF SLEEP
Insomnia, sleepwalking and dreams explained

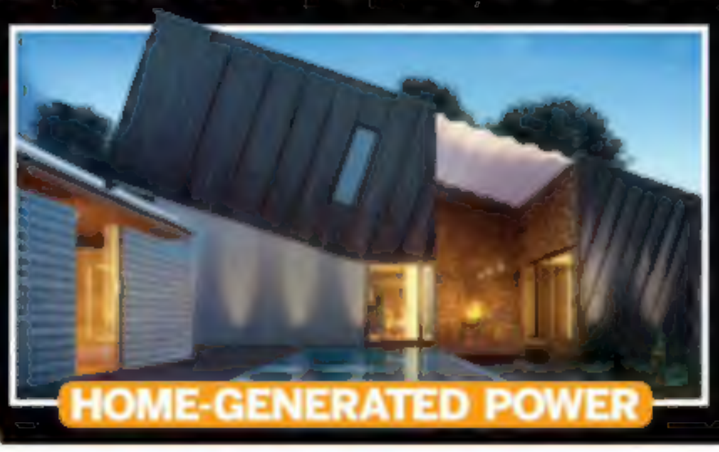
FITNESS GADGETS
How wearables track movement and more



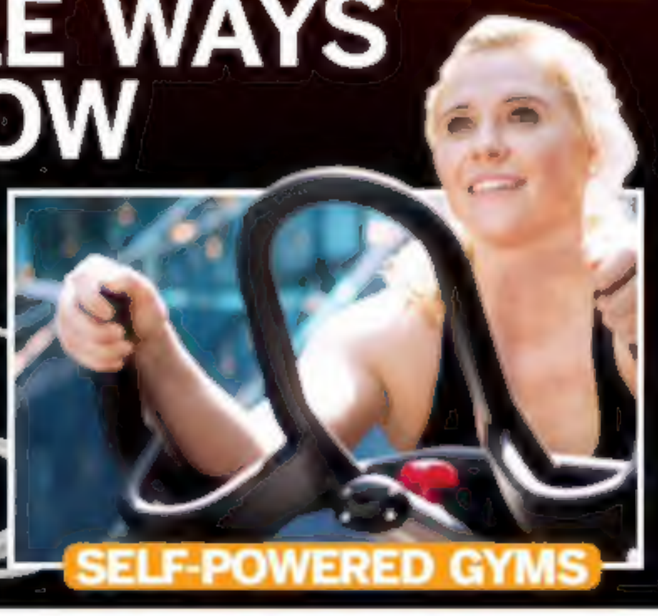
FUSION POWER

REVEALED: THE UNBELIEVEABLE WAYS WE CAN POWER TOMORROW


SPRAY-ON SOLAR CELLS


HOME-GENERATED POWER


WATER POWER


SELF-POWERED GYMS

3D-PRINTED CARS HAVE ARRIVED!

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ISSUE 70

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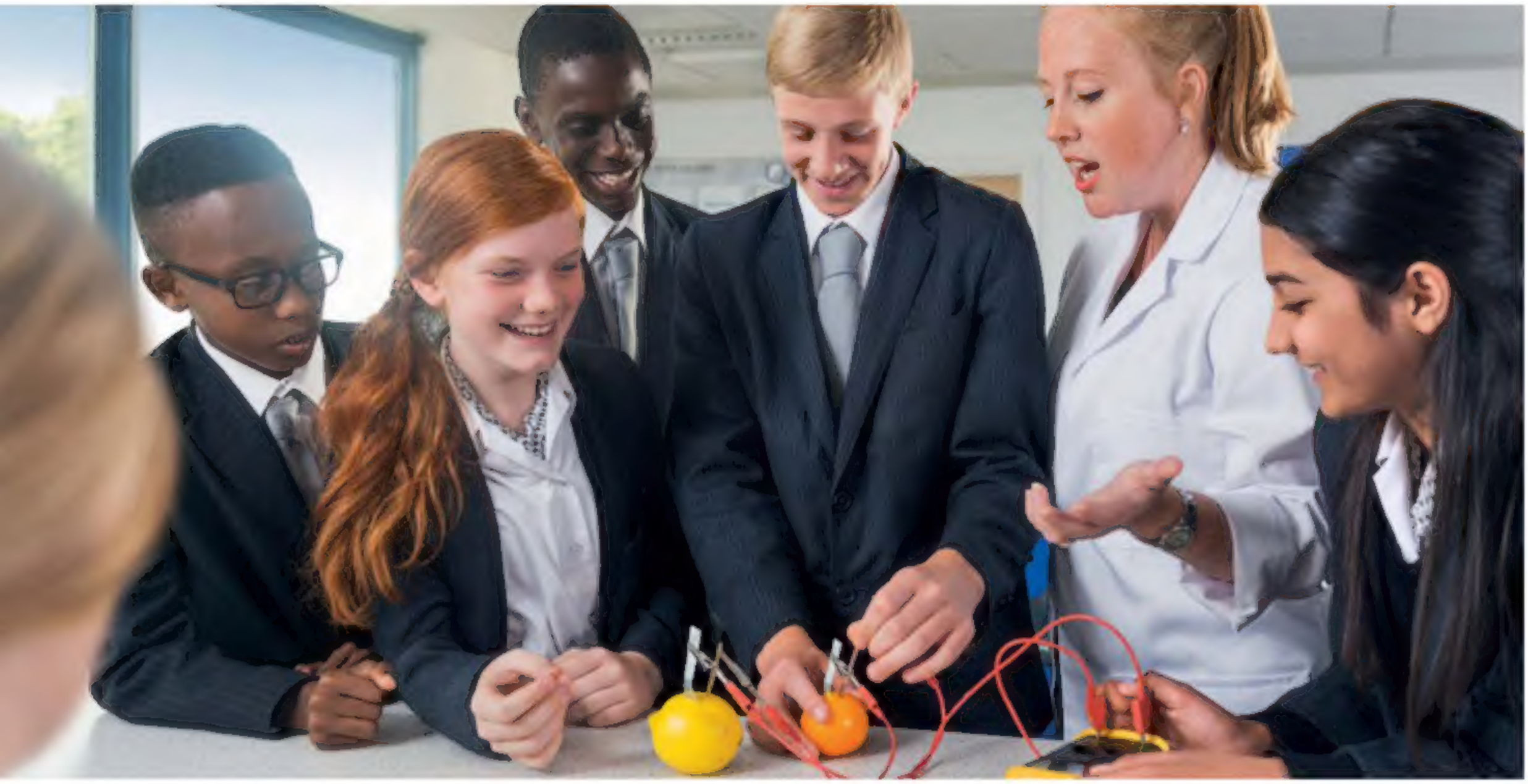

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ISSUE 70

WELCOME

The magazine that feeds minds!

Page 26
Discover the science behind how otters stay warm in water

This issue was the product of 50 cups of coffee, 15 cans of Diet Coke and too many of Jackie's homemade cakes to bother counting calories. What happened? After reading this month's Science of Sleep feature, I've discovered I was a victim of 'social jetlag' or, in other words, that back-to-work-feeling. A week's city break or theatre-going and late-night dining had tampered with my circadian rhythms, a daily timetable your bodily processes – including sleep and alertness – run by. Mess with it and the Starbucks staff are going to start scribbling down your name as soon as you set foot in the door.

Fortunately, there's also a section in the article on how to get a good night's sleep, meaning that next issue should be brought to you by the recommended fruit and veg intake. Sleep is a fascinating subject and by understanding the science behind it, we can learn how to get the most out of this crucial part of our day. We spend 25 years of our lives doing it, after all. Time to put the kettle on. White, no sugar, please.

Jodie

Jodie Tyley
Editor

Meet the team...

Andy
Art Editor
This issue, look out for the weirdest, toughest creature around. The 'water bear' is the only animal that can survive in space! Maybe it will become the new fashionable pet for humans on Mars...

Jackie
Research Editor
I managed to research two features in one go this issue by wearing a fitness band while napping. Hopefully next issue includes an article on how to raise a puppy.

Erlingur
Production Editor
The little quirks of nature are sometimes outright bizarre. Jellyfish Lake has been added to my must-visit list. I'm not entirely sure I'll want to go for a swim, though.

Jo
Senior Staff Writer
Never mind solar power and wind energy, we could soon be generating electricity for our homes from our own body heat, workout regimes and even poo, if Bill Gates gets his way.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

What's this picture of? Find out on page 54

Why do our furry friends lick us? **Page 28**

How does this jet break the sound barrier? **Page 62**

How does ultrasound work? **Page 38**

How do we search for alien planets? **Page 72**

What was school like 100 years ago? **Page 78**

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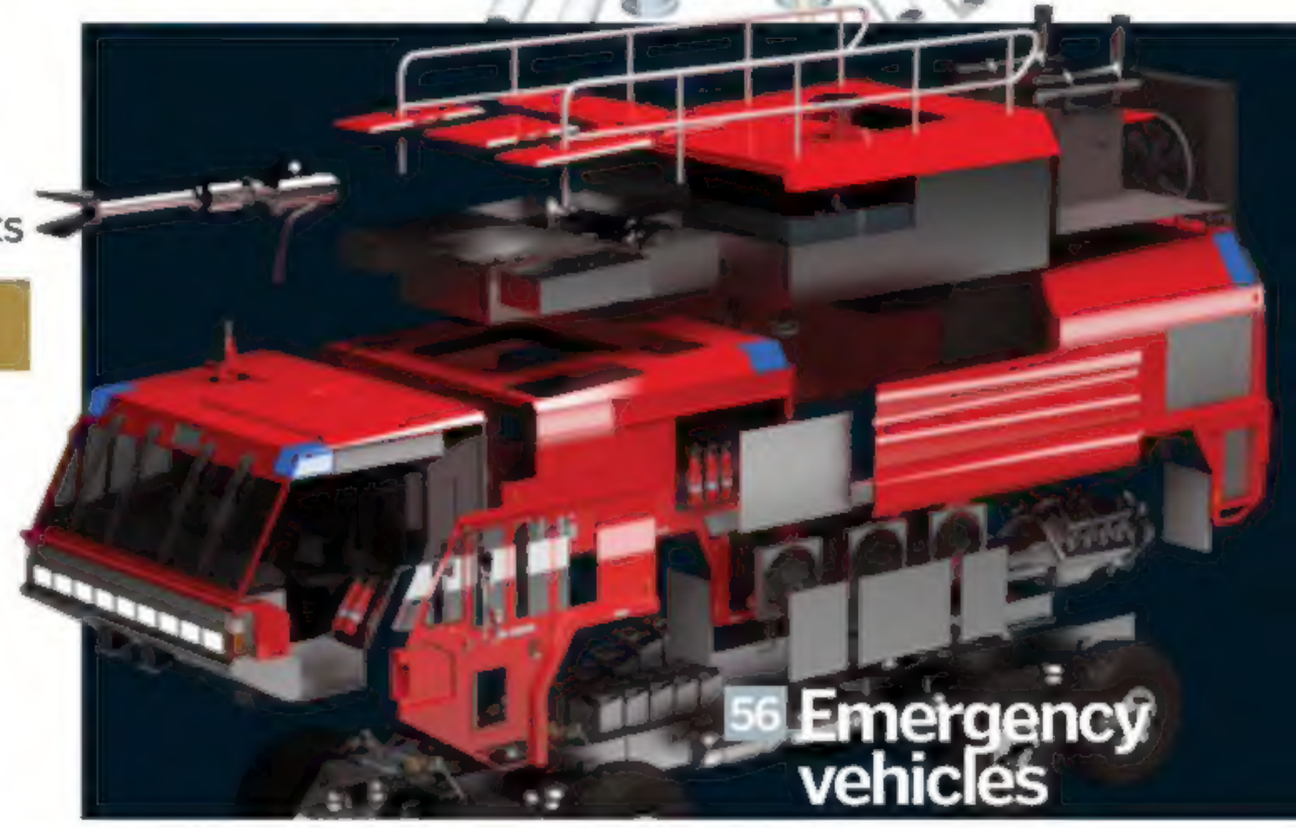
Fusion power and the other fascinating ways we can generate the power of tomorrow



Meet the experts...

Laura Mears
The science of sleep
Did you know there's no evidence to suggest eating cheese before bedtime gives you nightmares? For more brilliant sleep-related facts, head over to page 44 where Laura rips off the covers on the subject of sleep.

Hayley Paterek
Why do dogs lick people?
Hayley writes from home while fending off the affections of her adorable chihuahua, Dolly. This meant she was more than qualified to tells us why they can't stop licking us.

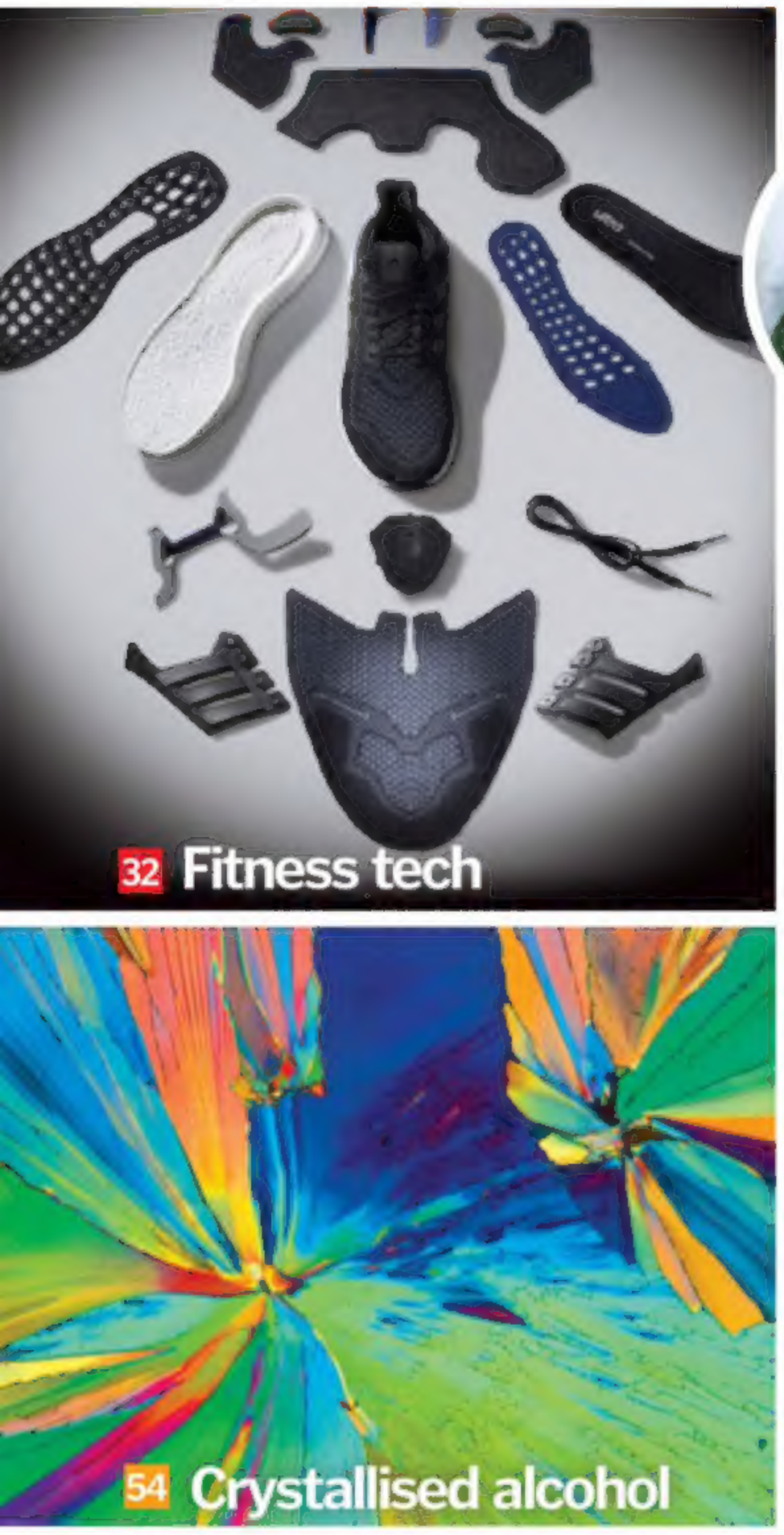
James Hoare
Roman sieges
The Editor in Chief of **History Of War** and **All About History** reveals how the Romans built their empire – by breaking down walls and using brutal tactics to force the enemy to surrender.

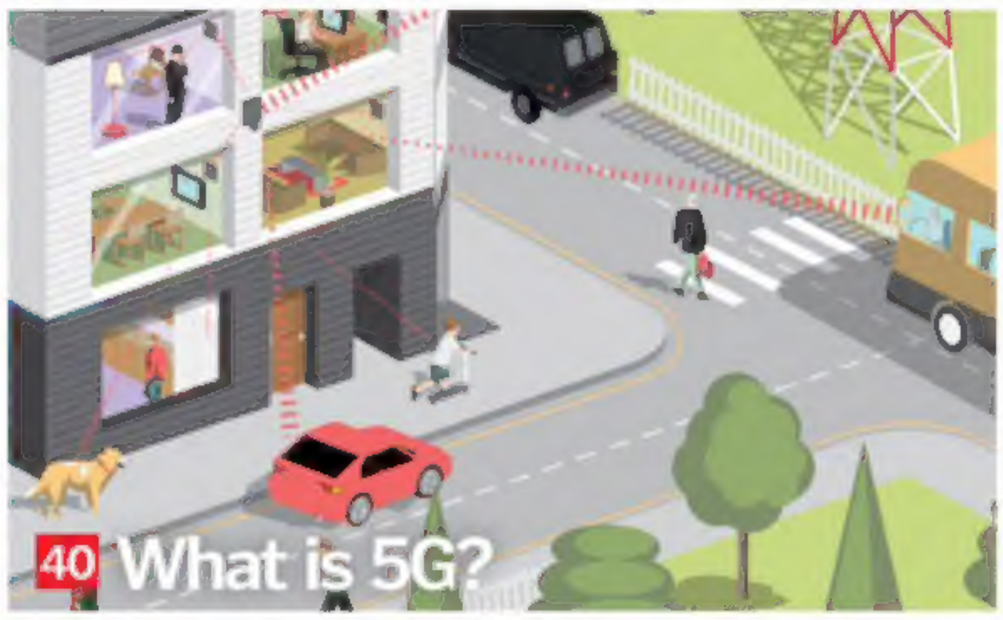
Jack Griffiths
Emergency vehicles
As a child, Jack wanted to a be a fireman. Now he just writes about the amazing tech they use to put out blazes. Turn to page 56 to see him live out his dream vicariously.

Steve Wright
How kilns work
Steve has no artistic skill whatsoever, but his way with words means he can explain how pottery creations are made, even if he can't mould them himself. See page 76 to find out for yourself.

What is the scientific reason behind zebras' stripes?
Find out on pg 12

REGULARS





Join our HOW IT WORKS Reader Panel today!

Take our three-minute survey at howitworksdaily.com/survey and win a place on our panel

Hi. We love making How It Works and we hope you love reading it too. But this year we want to make it even better, so we're asking for your help. By answering just a few questions, you could be selected to join our first-ever How It Works panel. I'm so excited to hear what you have to say and can't wait to learn more about you.

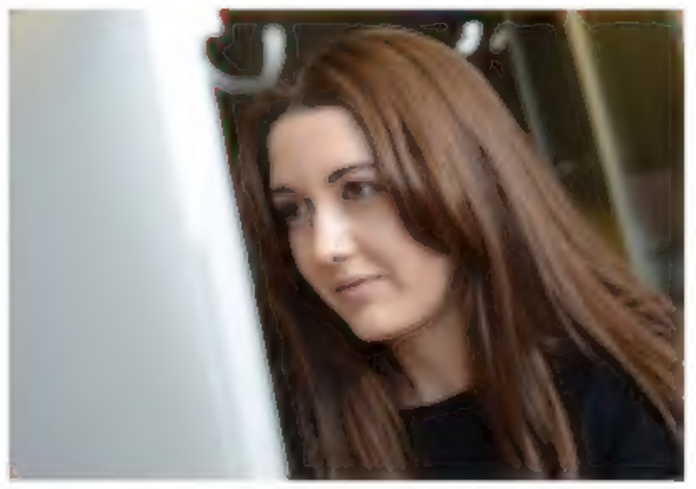
Jodie

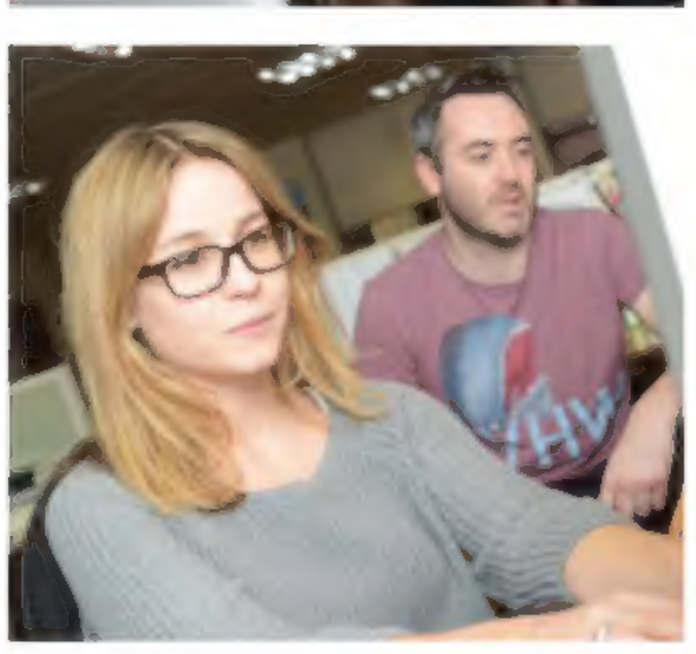
Jodie Tyley
Editor

Complete our survey to join our How It Works panel and:

- See new ideas and changes before anyone else
- Get invited to attend special events in your area
- Test third-party products for review
- Have a chance to meet the How It Works team
- Shape the future issues of the magazine
- Enter into exclusive competitions

Step 1 Complete survey → **Step 2** Get involved → **Step 3** Earn rewards





Complete our survey and win your place today

howitworksdaily.com/survey

A three-wheeled car-sharing service

Commuters can borrow Toyota's electric cars to get to the office

The French city of Grenoble has received a fleet of 70 compact Toyota i-Road and COMS vehicles for its Cité Lib service. Residents with a valid driver's licence can download an app that locates nearby fully charged vehicles, and pick one up to use for all or part of their journey, much like the Barclays Cycle Hire scheme in London. When they're done, they can drop it off at one of 27 charging stations, plugging it in to charge up for the next person to use. The three-year pilot scheme is already under way, with 35 three-wheeled i-Roads and another 35 four-wheeled COMS cars available for hire throughout the city.

Car meets motorbike

Toyota's two-seat, three-wheeled i-Road combines the easy manoeuvrability of a motorbike with the safety, weatherproofing and comfort of a car. This makes it ideal for negotiating city traffic and parking spaces, without the need for a helmet or protective clothing. The built-in Active Lean technology calculates the required angle of lean based on steering angle, vehicle speed and information from a gyro sensor in order to counteract the centrifugal force of cornering and enable a minimum turning radius of just three meters (9.8 feet). The vehicle, which has a top speed of 60 kilometres (37 miles) per hour, is also just 234.5 centimetres (92 inches) long and 87 centimetres (34 inches) wide, meaning that up to four vehicles can fit into a single standard parking bay.

A lithium-ion battery powers two 1.9-kilowatt electric motors mounted in the front wheels, and lasts for about 48 kilometres (30 miles) on a single three-hour charge.

The Toyota i-Road comes in a choice of five bright colours

In Grenoble, you can unplug a car from a charging point and borrow it for your journey

The Toyota i-Road uses Active Lean technology to help you negotiate traffic and tight parking spaces

Migrating birds play fair, switching formation to share the tough-going leader position

Mystery solved!

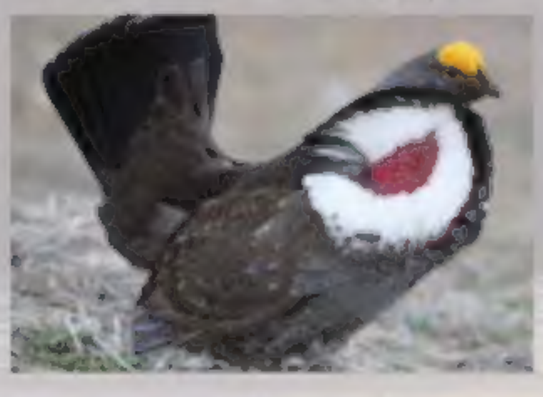
How migrating birds coordinate in mid-air

We already know that birds migrate in a V-formation to benefit from the extra lift produced by the wings of the bird in front, helping them to conserve some energy on their long journeys. However, by attaching GPS-based tracking devices to a flock of northern bald ibises, scientists have now been able to work out exactly how the birds decides who takes the lead. They discovered that they work in pairs, regularly switching places with the bird in front of them so that each one spends the same amount of time following as they do leading.

Bird migrations

Shortest

Blue grouse
North America's blue grouse lives in mountainous pine forests in winter, then travels just 300m (984ft) to deciduous woodland in spring.



Long

Bar-tailed godwit
This wader bird holds the record for the longest nonstop flight at 11,500km (7,145mi), reaching New Zealand from Alaska in nine days.

Longer

Northern wheatear
Despite only weighing as much as two tablespoons of salt, this tiny bird travels about 29,000km (18,000mi) every year.

Longest

Arctic tern
Travelling an average of 70,000km (43,500mi) a year between poles, the Arctic tern has the longest migration of any bird.

How to get more involved in science

Make amazing discoveries with British Science Week

From 13 to 22 March, people all over the country will be celebrating British science, technology, engineering and maths. Thousands of events will be hosted by schools, libraries, community centres and museums all over the country, or you can set up your own activities at home with the help of guides available on britishscienceweek.org. There will also be two nationwide citizen science projects that you can take part in, Worm Watch Lab and Nature's Calendar, as well as stargazing events celebrating the solar eclipse on 20 March.

19 May is Demo Day, when teachers will perform science demonstrations for students in the classroom

Visit britishscienceweek.org for a full list of events

The original star that exploded in the Cassiopeia A supernova was 15-20 times bigger than the Sun

Secrets of the bubbly supernova

Mapping the powerful explosion that ripped apart a star

Cassiopeia A is the remnants of a supernova, formed 340 years ago when a massive star exploded to form a neutron star. Its material collapsed inward before bouncing outward again. This left behind gas or bubbles, in its interior, but until now scientists didn't know how this happened. By creating a 3D model of the supernova, they found the cavities inside are caused when radioactive nickel-56 decays into iron, generating energy. The plumes of nickel this produces push away non-radioactive material as they move, creating cavities.

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

Zebras' stripes help cool them down

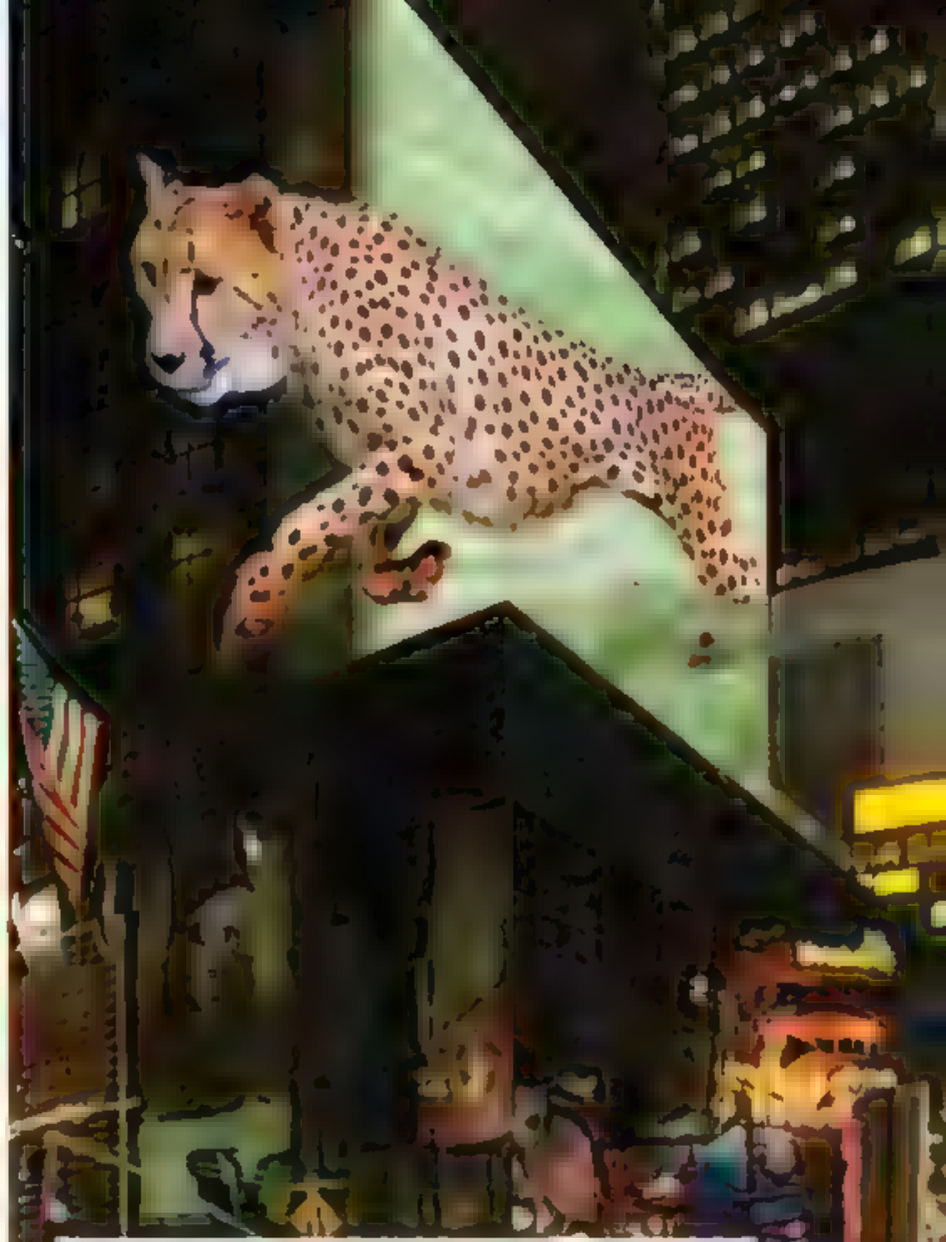
The purpose of zebras' distinctive stripes has never been confirmed, but a new study suggests they could help with thermoregulation. Researchers found that zebras living in cooler climates are less stripy than those living in hotter environments. It is believed that as air moves faster over the black stripes, but slower over the white stripes, it creates a cooling convection current over the zebra's body.

A new antibiotic has been found

A new antibiotic called teixobactin could soon be used to treat resistant diseases such as MRSA and tuberculosis. It was discovered when scientists isolated single cells of soil bacteria and then buried them back into the soil so that they could grow in their natural environment. This lead to the discovery of 25 new antibiotics, of which teixobactin is the most promising as it destroys bacterial cell walls.

Beethoven's heartbeat influenced his music

The music of famous composer Ludwig van Beethoven could quite literally have come from the heart. A cardiologist, a medical historian and a musicologist studied his most renowned works and have identified predictable patterns that match the irregular heartbeat associated with arrhythmia.

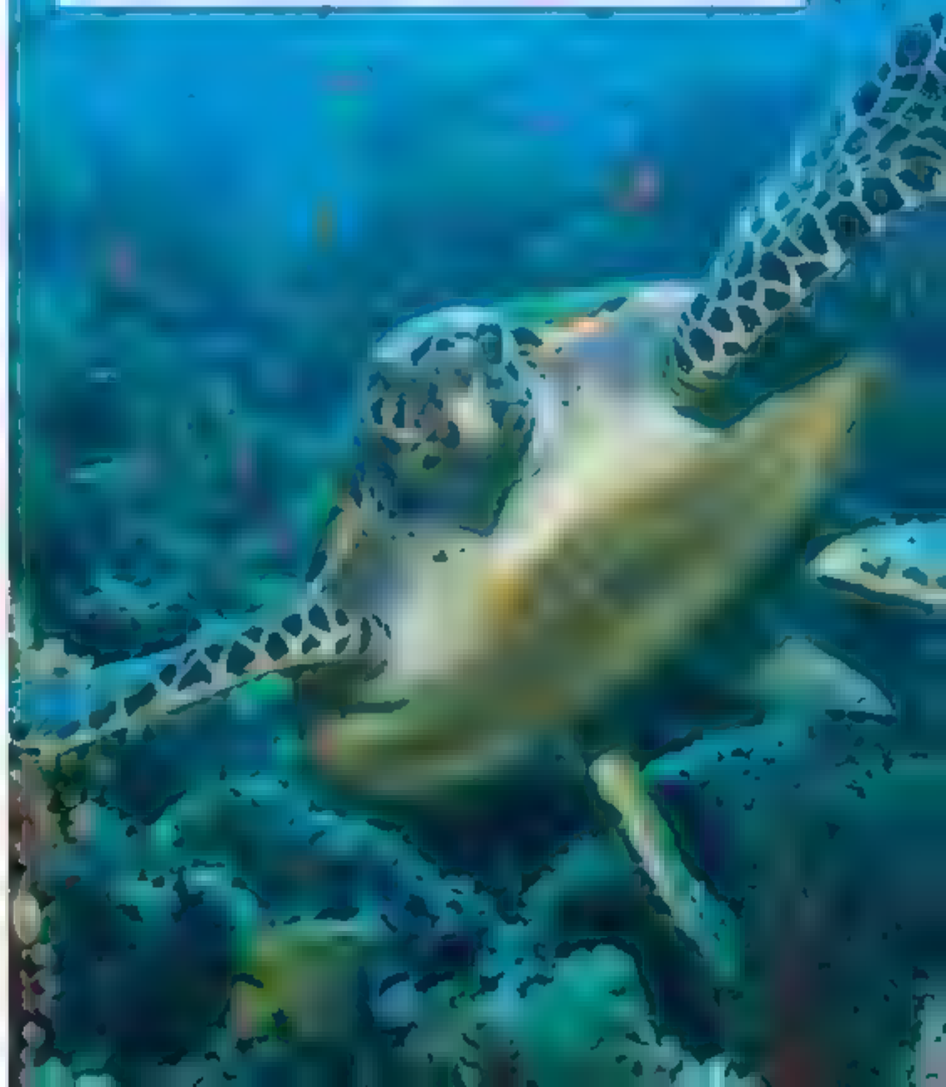


We could soon view 3D without glasses

TriLite Technologies have developed digital billboards that show 3D images you don't need special glasses to view. Rather than using LEDs like modern billboards, each pixel contains a red, green and blue laser diode and a movable micro-mirror. It works by beaming a different image into the viewer's left and right eye, creating a stereoscopic 3D effect.

Sea turtles use magnetic fields

Sea turtles always nest on the same stretch of coastline where they hatched, and now scientists have worked out how they find their way there. They observed that sea turtles packed themselves into a shorter stretch of beach when the magnetic signatures of adjacent locations along the coast naturally shifted closer together. This suggests that the turtles imprint on the unique magnetic field of their birthplace to help them find it as adults.

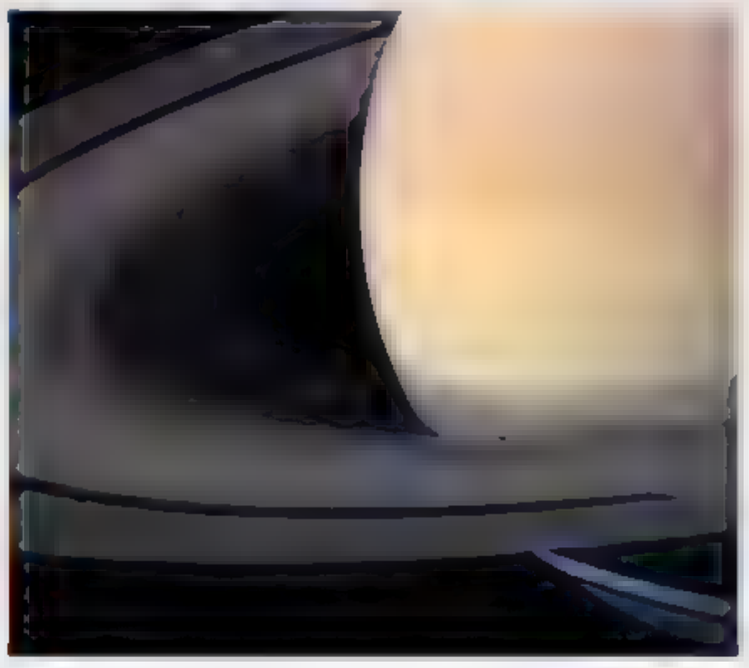


Get from San Francisco to LA in three hours

By 2029, the USA will get its first high-speed rail system, allowing commuters to travel from San Francisco to the Los Angeles basin at speeds of over 322 kilometres (200 miles) per hour. Eventually the system will also extend to Sacramento and San Diego, with 1,287 kilometres (800 miles) of track and 24 stations.

Saturn's location has been pinpointed

By combining information from the Very Long Baseline Array (VLBA) system of radio-telescope dishes spread between Hawaii and the Virgin Islands and signals from NASA's Cassini spacecraft currently orbiting Saturn, astronomers have been able to pinpoint Saturn's barycentre (centre of mass) within four kilometres (2.5 miles). This is 50 times more accurate than the measurements provided by ground-based telescopes.



2015 will be a full second longer

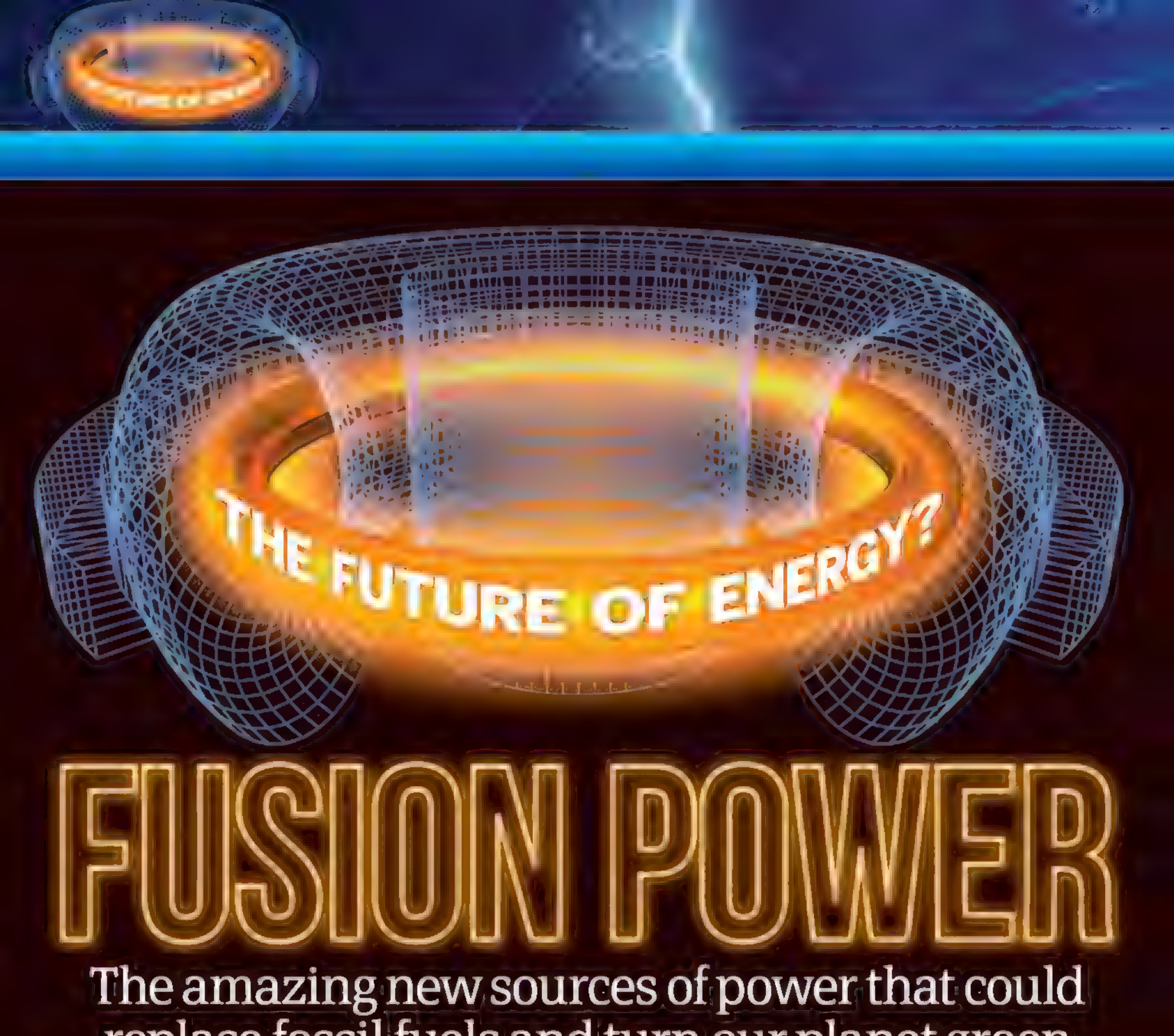
At the end of 30 June 2015, the world's atomic clocks will switch to 23:59:60 before ticking over to 00:00:00 on 1 July. This is because the Earth's rotation is gradually slowing down and so an extra second must be added to compensate. The last leap second was added in 2012, and a lot of websites struggled to cope with the change.

The truth about the smell of rain

In 1964, the earthy smell of rain was discovered to come from oils and chemicals in the soil. 50 years on, scientists have now discovered how this scent is released. By filming water droplets with high-speed cameras they found that raindrops trap tiny air bubbles when they hit a porous surface, such as soil. These bubbles fizz upward and are released as aerosols, which carry aromatic elements, along with bacteria and viruses.

NASA is sending unusual cargo to Pluto

The ashes of Clyde Tombaugh, the American astronomer who discovered Pluto in 1930, are on their way to the dwarf planet on board NASA's New Horizons spacecraft. The probe's closest flyby of Pluto is expected to occur on 14 July 2015.



FUSION POWER

The amazing new sources of power that could replace fossil fuels and turn our planet green

Currently, our planet gets most of its power from coal, oil and gas. These so-called fossil fuels were formed from the remains of living organisms existing millions of years ago, and when burned, release heat energy that can be turned into electricity. However, they are also very harmful to the environment, as burning fossil fuels also gives off a lot of carbon dioxide, a greenhouse gas that contributes to global warming.

As the Sun's energy beats down on Earth, approximately 70 per cent of it gets absorbed by the land and oceans, while 30 per cent is reflected back into space. However, the 70 per cent absorbed by Earth is eventually radiated back out into the atmosphere in the form of infrared energy. Greenhouse gases then absorb this energy, but also emit heat in the process, which warms the Earth's surface and lower atmosphere. This process occurs naturally and is what keeps the planet warm enough for living things to survive on it. However, a dramatic increase in greenhouse gas emissions since the Industrial Revolution has also caused a big rise in the average surface temperature of the Earth. This in turn has caused the world's glaciers and ice shelves to melt faster, which will lead to a rise in sea levels resulting in the flooding of low-lying areas of coast. An increase in global temperatures fuels more fierce and devastating tropical storms and hurricanes, and could also trigger severe droughts in some parts of the world.

Even if burning fossils didn't have this destructive power, it would still be important for us to find alternative sources of energy. Although fossil fuels are technically renewable, as they are made from living organisms, that fact we are using them up at a much faster rate than they can be formed means we will eventually run out.

Some renewable sources of energy, such as solar, wind and hydroelectric power, are already being used, but these come with their own problems that prevent them from replacing fossil fuels altogether. However, as we continue to find innovative new ways to harness unused energy, our planet could soon become a green, self-powered machine.

Emergence of fusion power

Generating energy by mimicking the Sun could be the most efficient renewable source yet

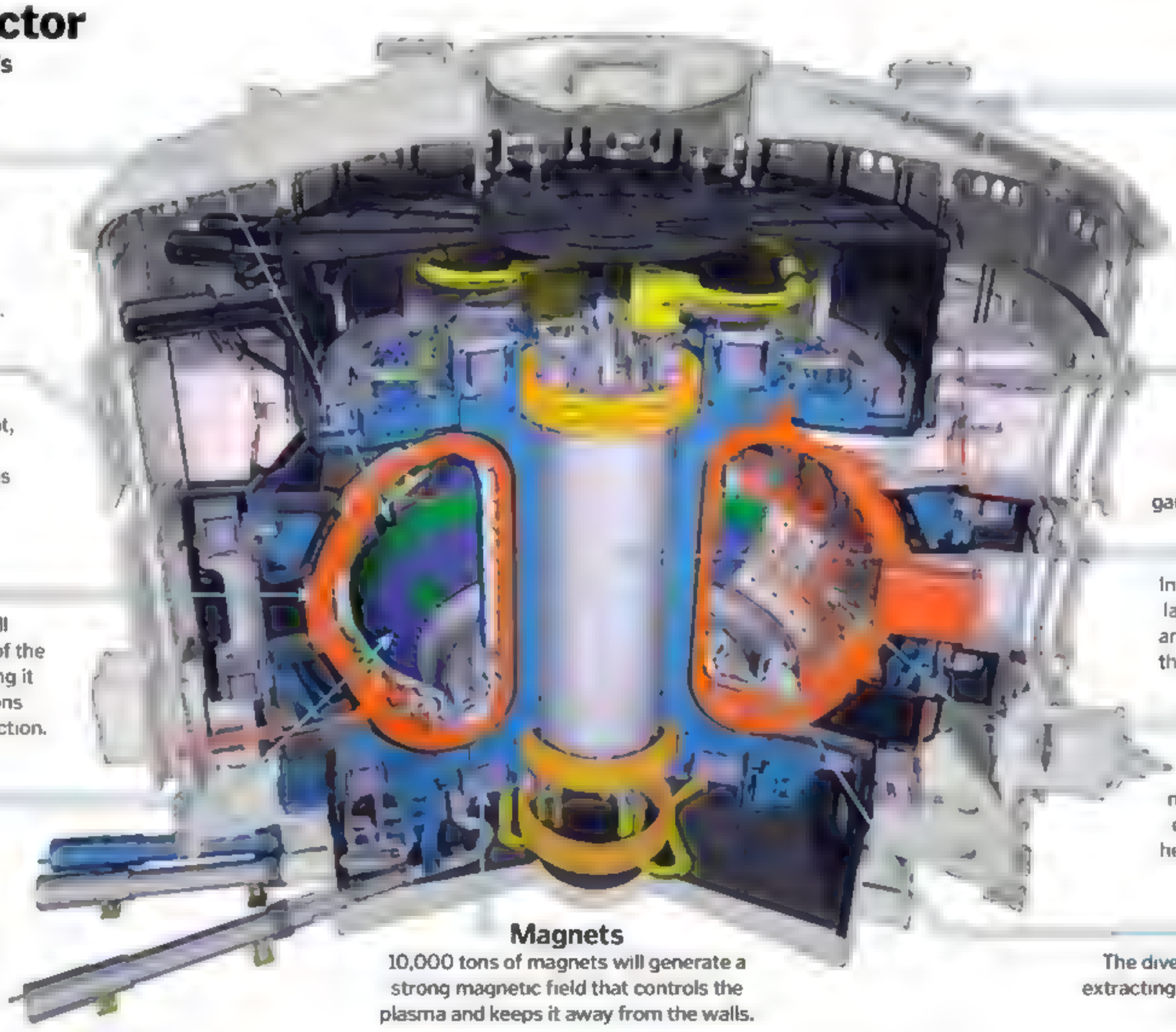
Stars such as our Sun produce huge amounts of energy using a process known as fusion. When exposed to extreme heat and high pressures in the star's core, hydrogen atoms are stripped of their electrons to expose their nuclei. This soup of nuclei and electrons is known as plasma, the fourth state of matter. When plasma is heated, the hydrogen nuclei move quickly and collide, fusing together to produce helium and a great deal of energy.

Due to the clean and efficient nature of this process, scientists have now developed a way to replicate it here on Earth, in the hope that it could eventually eliminate the need for fossil fuels. To do this, they have built enormous fusion reactors, which use magnetic fields to produce temperatures of 150 million degrees Celsius (270 degrees Fahrenheit), ten times hotter than Sun's core, and control plasma within a ring-shaped chamber called a tokamak. The fuels used in the reactor are the hydrogen isotopes deuterium, extracted from water and tritium, produced from lithium found in the Earth's crust. Our current supply will last for millions of years, and just one kilogram (2.2 pounds) can provide the same amount of energy as 10,000 tons of fossil fuel. Plus, the main by-product of fusion power is a small amount of helium, which will not pollute the atmosphere.

Although the technology is already in place to create fusion power, current fusion rectors consume more energy than they produce. The challenge now is to build a reactor that is big enough to serve as a working power plant, and the ITER project in France is the first step. ▸

The ITER fusion reactor

Plans for the world's largest tokamak



8,000 tons of tokamak
The 19 x 11m (62 x 36ft) vacuum vessel will be twice as large and 16 times as heavy as any previously built tokamak.

Cryosat
The entire vessel will be enclosed within a cryosat, essentially a giant refrigerator that insulates the superconducting magnet system.

Blanket
440 blanket modules will cover the inner surface of the vacuum vessel, protecting it from high-energy neutrons produced during the reaction.

Vacuum vessel
A double-walled stainless steel container will house the plasma particles, which will spiral around the donut-shaped chamber creating a fusion reaction.

Bioshield
The cryosat will be completely surrounded by the bioshield, a protective concrete layer that is 2m (6.6ft) thick at the top.

Diagnostics
The plasma performance inside the vessel will be observed using monitoring systems such as pressure gauges and neutron cameras.

Central solenoid
In the centre of the reactor, a large transformer will create an electric current to heat up the fuel and produce plasma.

Heating
To initiate the reaction, an external heating system, neutral beam injections and electromagnetic waves will heat the hydrogen plasma to 150mn°C (270mn°F).

Divertor
The divertor is the exhaust system, extracting helium ash, heat and other impurities from the vessel.

Magnets
10,000 tons of magnets will generate a strong magnetic field that controls the plasma and keeps it away from the walls.

Renewable vs non-renewable energy

What will we do when all the fossil fuels run out?

We have already discovered lots of new sustainable sources of energy in our mission to replace fossil fuels, and it's likely we will discover several more as science and technology progresses. However, renewable sources currently only supply about ten to 20 per cent of our energy needs, as obstacles such as cost and efficiency mean we are still relying on coal, oil and gas a great deal. As with most forms of technology, it's likely that cost will decrease and efficiency will increase over time, but what else is stopping us from switching to solar, wind and all the other renewable sources available?

Wind farm

(renewable)

PRO: Can power single households as well as entire towns
PRO: Gives off no greenhouse gases
CON: Noisy and expensive to set up
CON: Reliant on wind

Tidal

(renewable)

PRO: Predictable and reliable energy source
PRO: Gives off no greenhouse gases
CON: Expensive to set up
CON: Can have negative effects on the environment

Sources of energy

The pros and cons of all our available energy options

Biomass

(renewable)

PRO: Can provide electricity and fuel
PRO: Cheap and abundant source of energy
CON: Gives off CO_2 when burned
CON: Only renewable if crops are replanted

Nuclear power plant

(non-renewable)

PRO: Raw materials are efficient and relatively cheap
PRO: Does not give off greenhouse gases
CON: Nuclear waste is highly toxic
CON: Nuclear reactors are expensive to run

Coal
(non-renewable)

- PRO: Cheap to mine
- PRO: Abundant supplies worldwide
- CON: Gives off CO_2 when burned
- CON: Destruction of land

Solar
(renewable)

- PRO: Solar panels are quiet and low maintenance
- PRO: Gives off no greenhouse gases
- CON: Panels are expensive to manufacture
- CON: Reliant on sunlight

Hydroelectric
(renewable)

- PRO: Creates water reserves as well as energy
- PRO: Gives off no greenhouse gases
- CON: Can cause flooding of local areas
- CON: Expensive to set up

Geothermal
(renewable)

- PRO: No harmful gases are produced
- PRO: Abundant energy supply
- CON: Expensive to set up
- CON: Reliant on volcanic activity

Oil
(non-renewable)

- PRO: Easy to extract and distribute
- PRO: Powerful and versatile fuel
- CON: Gives off CO_2 when burned
- CON: Difficult and costly to find new sources

Gas
(non-renewable)

- PRO: Cleaner than oil or coal
- PRO: Easily transported
- CON: Gives off CO_2 when burned
- CON: Dangerous to work with

Timber
(renewable)

- PRO: Cheap and abundant source of energy
- PRO: Sustainable, long term source
- CON: Gives off CO_2 when burned
- CON: Only renewable if trees are replanted

Why do we need renewable energy?

Facts and figures about our current energy supplies

Coal reserves
The USA has the largest coal reserve, with Russia coming in second and China third.

Sea levels rise
The rise in atmospheric temperature is causing the world's ice caps to melt, leading to a rise in sea levels.

Gas reserves
The country with the largest natural gas reserves is Iran, followed by Russia and Qatar.

Extreme weather
Global warming also affects weather patterns, leading to more extreme weather, such as droughts, flooding and hurricanes.

Global warming
Gases such as carbon dioxide, which are given off by burning fossil fuels, trap heat inside the Earth's atmosphere.

Coal supply
In circa 250 years, the world's supply of coal is expected to run out.

Oil reserves
Venezuela has most of the world's proven oil reserves, followed by Saudi Arabia, Canada, Iran and Iraq.

Oil supply
The world's oil supply is expected to run out in about 50 years.

Gas supply
Our supply of natural gas is likely to run out in about 70 years.

Limitations of green energy

What's holding us back from becoming a fossil fuel-free planet?

Despite the infinite supply of energy available to us from renewable sources, we still rely heavily on fossil fuels. Unfortunately, there are many issues that still need to be overcome before we can become completely green.

One of the main obstacles is cost, as the infrastructure required for most renewable energy sources is expensive, especially when compared to that of fossil fuels. Solar panels, wind turbines, hydroelectric dams, tidal barrages and nuclear fusion plants are all expensive to build and storing any excess energy they produce can also be costly.

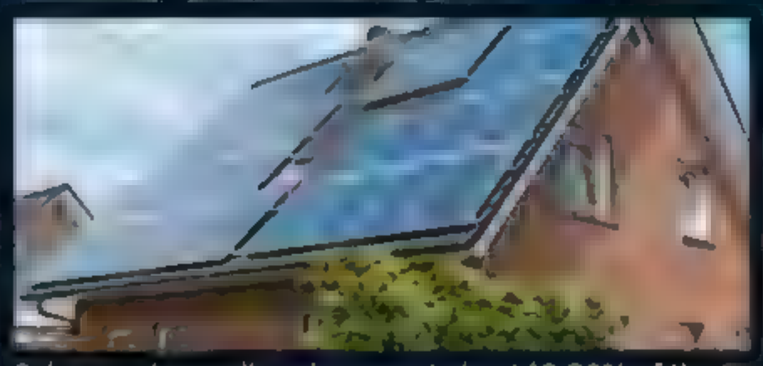
The reliance on unpredictable weather is another major issue for some forms of renewable energy. Wind, for example, is very inconsistent, and of course solar energy is only harvested in significant amounts during clear daylight hours. Therefore, fossil fuel energy is still required as a back-up when the conditions aren't quite right.

At the moment, technology used to harvest renewable energy is also not particularly efficient. Vast areas of land or sea need to be covered with solar panels or wind turbines in order to generate the same amount of power produced by non-renewable sources. This can generate opposition from local residents, as some people believe wind farms spoil the countryside. Local ecosystems can also be negatively affected by some renewable energy sources. For example, hydroelectric dams disturb the flow of rivers, disrupting native wildlife and local settlements, and tidal barrages can be harmful to marine life.

Of course, some sustainable solutions are severely restricted by location anyway. For example, geothermal energy can only be produced near areas of volcanic activity, and tidal energy requires strong tides.

Wind turbines can operate in wind speeds up to ca 60m/s (197ft/s). If gales are any stronger they shut down to avoid damage

Hydroelectric power is reliant on rainfall, and causes flooding of land that can damage human and animal habitats

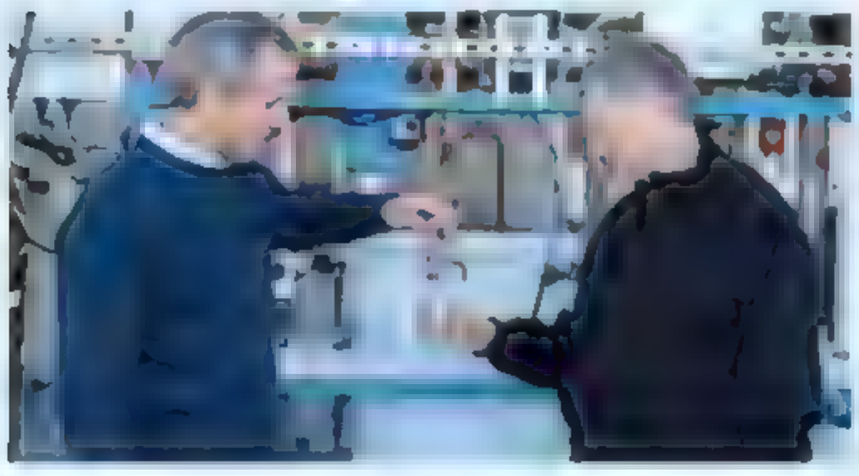


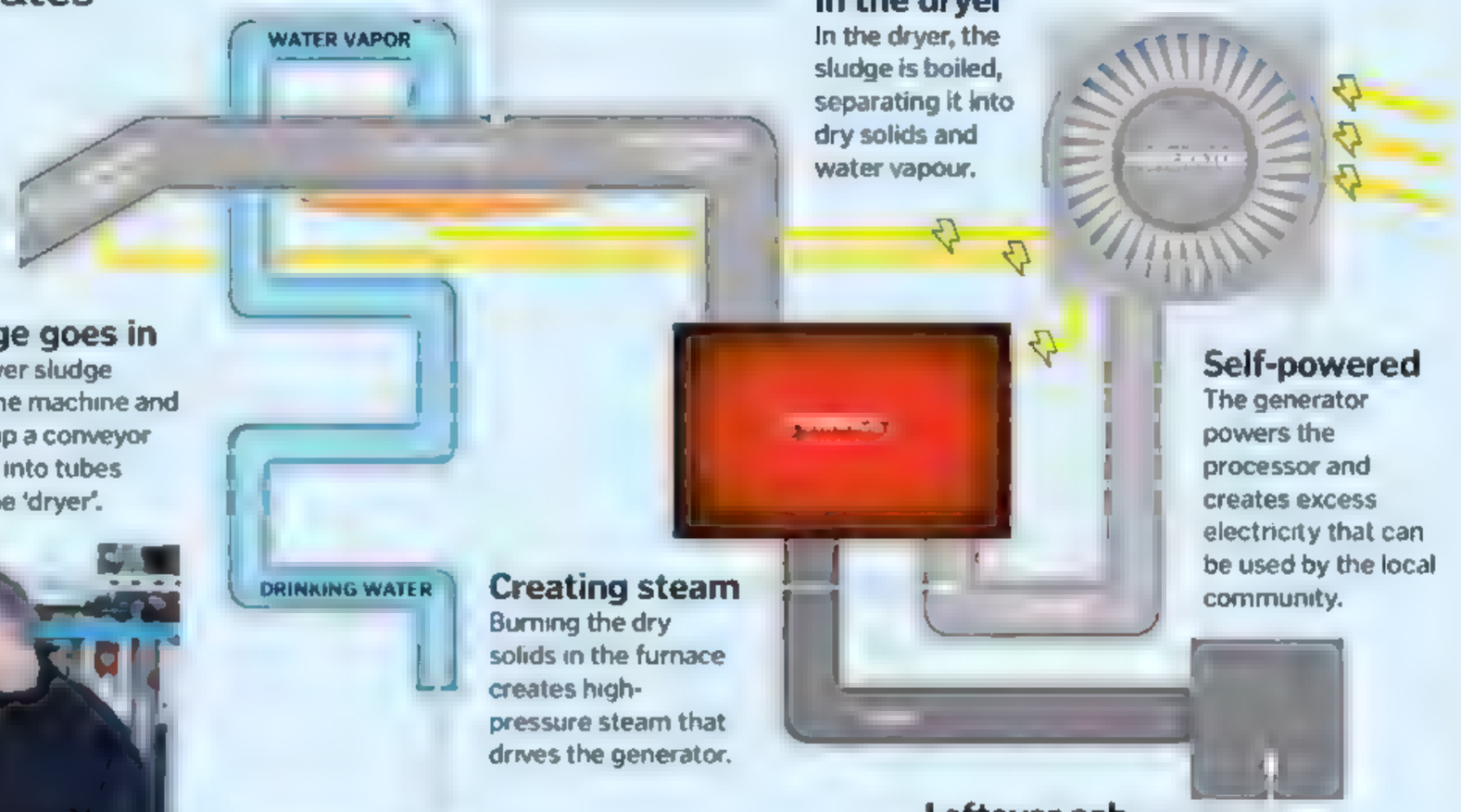
Solar panels usually only convert about 10-20% of the energy that reaches them into electricity, and become less efficient in very high temperatures

Sewage as power

The incredible poo-powered machine backed by Bill Gates

The Janicki Bioenergy Omni Processor is new type of sewage treatment plant that also creates renewable energy. It serves as a safe repository for human waste, preventing the sewage from being dumped into rivers or oceans, and providing clean drinking water and electricity without releasing harmful greenhouse gases.





Sewage goes in
Wet sewer sludge enters the machine and travels up a conveyor belt and into tubes called the 'dryer'.

In the dryer
In the dryer, the sludge is boiled, separating it into dry solids and water vapour.

Creating steam
Burning the dry solids in the furnace creates high-pressure steam that drives the generator.

Self-powered
The generator powers the processor and creates excess electricity that can be used by the local community.

Drinking water
The water vapour is run through a cleaning system to produce pure water that is safe to drink.

Leftover ash
The dry solids are fed into a furnace, where they are turned into ash that is pathogen-free.

Sunshine-powered water purifier

The solar-powered machine that makes contaminated water safe to drink

The Desolenator uses energy and heat from the Sun to turn dirty or salt water into distilled water. It is entirely self-contained and can provide water-stressed towns and villages with a cheap, reliable and convenient source of hydration. Currently still in the development stage, the device could be put to use by the end of 2015. ▶

Desolenator power

A solar panel that distils water too

Water vapour
When the water evaporates, the vapour is fed back through the cavity where it is condensed into distilled water.

Boiling unit
The water then goes into a boiling unit powered by a battery that stores energy from the solar panel.

Insulated panel
The solar panel is insulated with foam underneath and double glazing on the top, so it heats up to very high temperatures.

Water cavity
Rainwater flows through a cavity between the double glazing and solar panel, heating to about 90°C (194°F).

Self-cooling
The water also cools down the solar panel, aiding its efficiency so that it produces more energy.

Family supply
A unit the size of a large flat-screen television can produce 15l (3.3ga) of drinking water per day.

Easy transportation
All-terrain wheels, a foldable legs and rugged handles make the unit very easy to move and store.

Remote monitoring
The circuit also contains a GSM chip that transmits the unit's performance data to a service company to allow for remote monitoring.

LCD screen
A small amount of energy from the solar panel is run through a circuit, powering an LCD screen that shows the unit's performance.

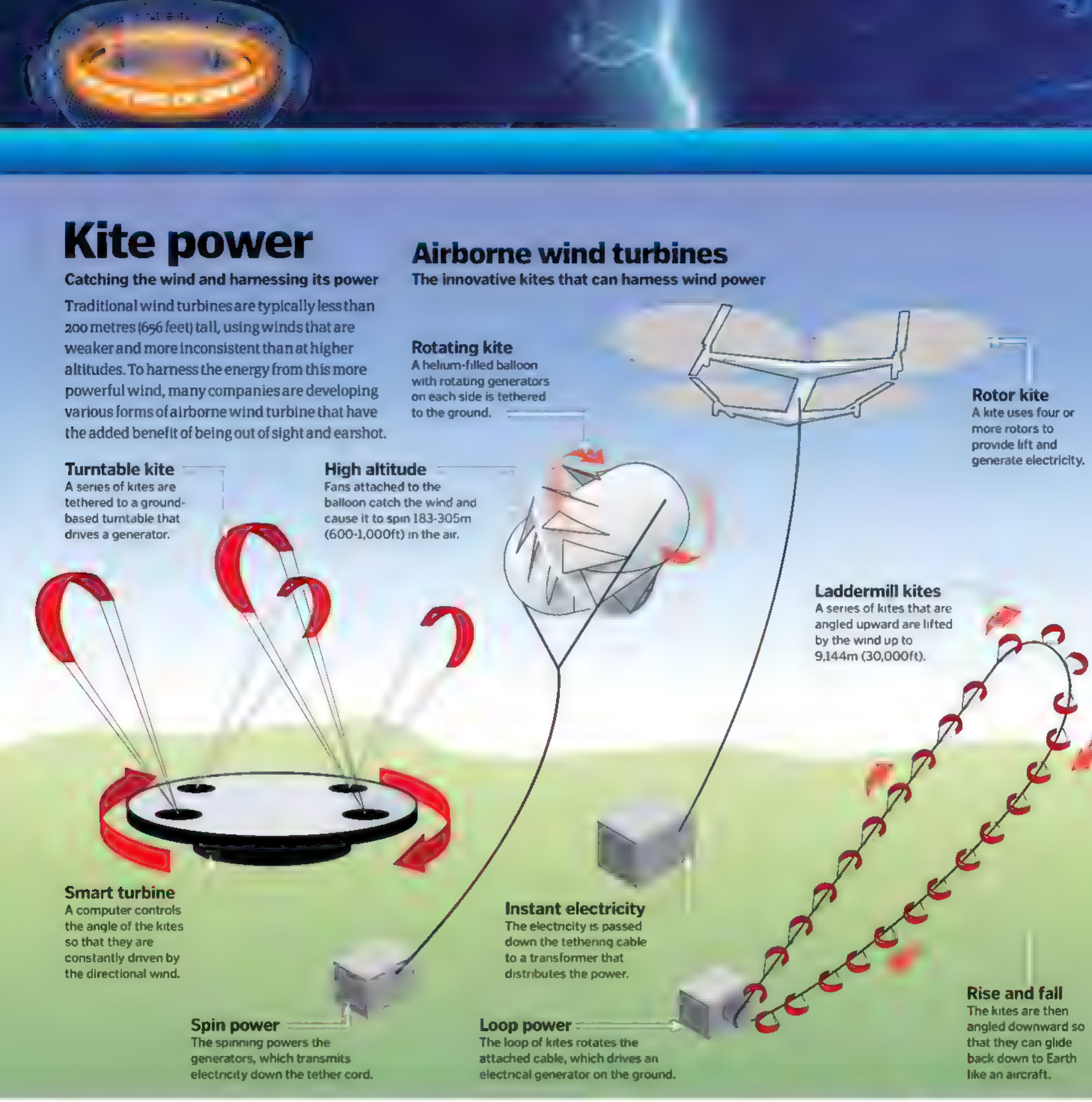
Kite power

Catching the wind and harnessing its power

Traditional wind turbines are typically less than 200 metres (656 feet) tall, using winds that are weaker and more inconsistent than at higher altitudes. To harness the energy from this more powerful wind, many companies are developing various forms of airborne wind turbine that have the added benefit of being out of sight and earshot.

Airborne wind turbines

The innovative kites that can harness wind power



Spray-on solar cells

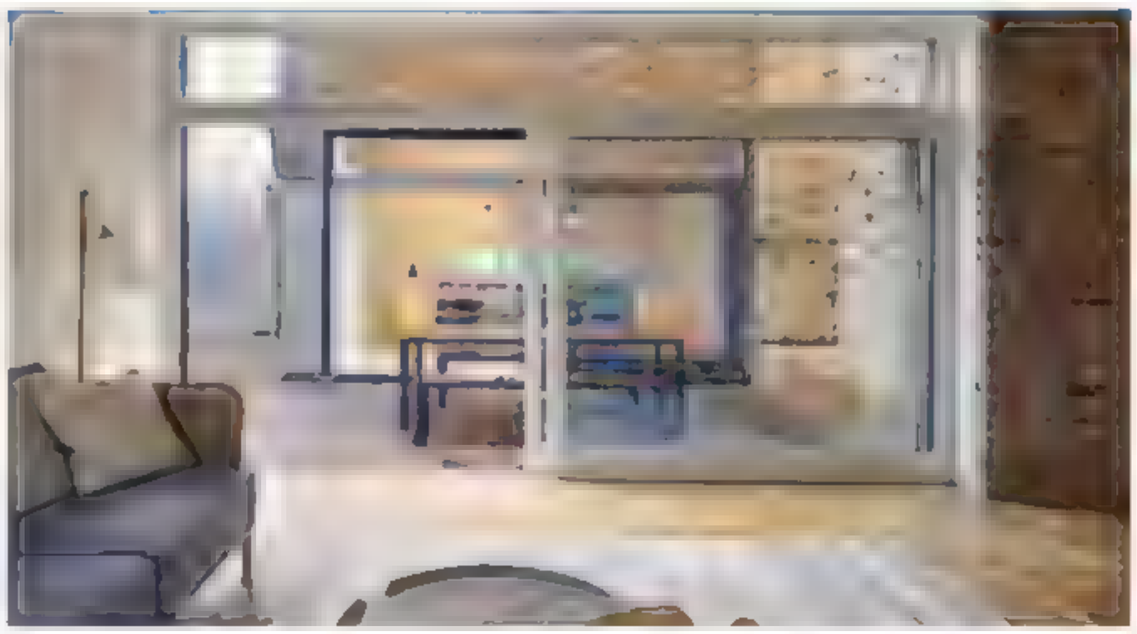
Scientists at the University of Toronto have developed a new method of spraying solar cells onto flexible surfaces. Their SplayLD system uses colloidal quantum dots (CQD), nanometre-sized crystals containing only a few thousand atoms, that absorb sunlight and turn it into electricity. A liquid containing these CQDs is then sprayed onto a surface such as plastic, glass or even clingfilm, in single layer. Next, a chemical treatment is sprayed on top, transforming the CQDs from electrically insulating to electrically conductive, before the surface is rinsed clean. This process is then repeated to build up 65 to 85 layers.

Until now, the only way to carry out this process was through batch processing, requiring expensive infrastructure and a slow assembly line. However, the SprayLD system can now be applied using something resembling a newspaper printing press. So although the CQDs are half as efficient as conventional solar cells, they are also less than half as expensive to manufacture, meaning a better value for money.

Eco-house

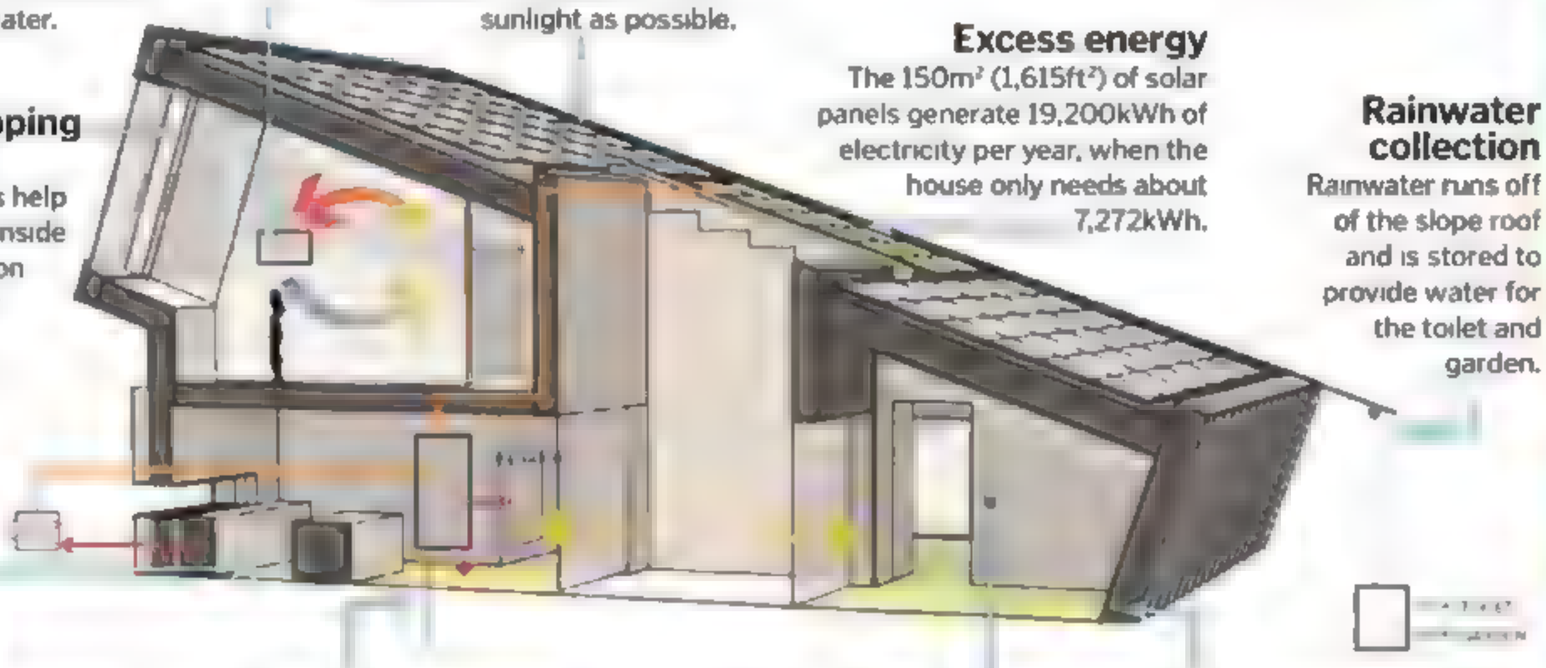
The family home that generates more energy than it needs

The ZEB Pilot House, created by Norwegian architect firm Snøhetta, uses solar and geothermal power to produce three times more energy than it needs. In fact, the surplus energy it generates is enough to power an electric car year-round. The building, situated in Larvik, Norway, is big enough to house a family. ▶



ZEB Pilot House

Tour the ZEB Pilot House



Circulating heat
A heat exchanger uses excess heat from indoor air to heat the incoming air and tap water.

Solar panel roof
The roof, clad with solar panels, is sloped 19 degrees toward the southeast to capture as much sunlight as possible.

Excess energy
The 150m² (1,615ft²) of solar panels generate 19,200kWh of electricity per year, when the house only needs about 7,272kWh.

Heat-trapping windows
The windows help to trap heat inside the building on cold days for greater efficiency.

Rainwater collection
Rainwater runs off of the slope roof and is stored to provide water for the toilet and garden.

Heating system
The house features efficient under-floor heating, and just one radiator on each floor.

Geothermal energy
An underground well harvests geothermal energy, using pressurised steam from hot water to power a generator.

Smart control
The interior light and air is automatically controlled by smart monitors based on usage and need.

Good thermal mass
High-density building materials, such as concrete and brick, absorb and store heat energy, stabilising the temperature.

Charge your phone using salt & water

People power

Could our bodies soon become our own renewable power station?

The human body is one big energy factory. Calories go in, by way of food, and they in turn power our organs and muscles, generating excess heat. Simply going for a walk could generate 163 watts of power, but the big challenge is working out how to efficiently turn this into usable energy.

Scientists are exploring lots of innovative ways to harness human power, and one such method involves piezoelectricity, which can be produced from the pressure applied to a surface through motions such as walking.

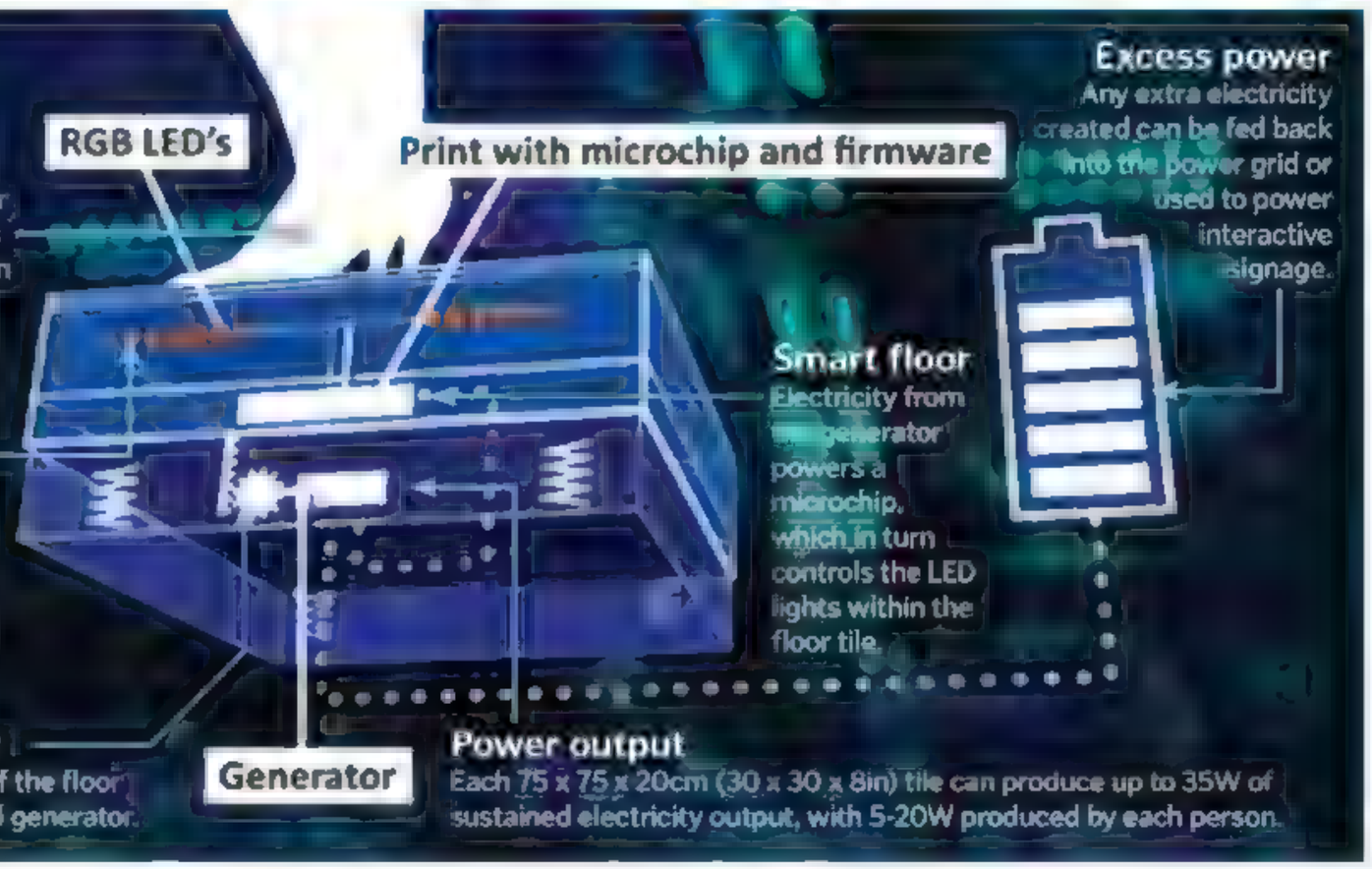
When pressure is applied to an object containing atoms or molecules arranged in a very orderly way, also known as crystals, the charges are forced out of balance. The compressed side gains a positive charge while the opposite develops a negative charge, and when the pressure is relieved an electric current flows between them, which can be stored and used as a power source. Although this is proven to work, it only generates a very small amount of electricity, unfortunately insufficient for powering most electronic devices.

Another method being explored for harnessing kinetic energy uses magnetic fields. Scientists at the HSG-IMIT research centre in Germany have developed a shock harvester and a swing harvester device that can fit inside a regular shoe. When the heel strikes the ground or the foot swings between steps, a magnet within each harvester moves past a stationary coil. This generates an electric current, creating a very small three to four milliwatts of energy. Although not enough to charge a phone, it can power small sensors and transmitters that can track your journey, and the inventors hope it can eventually be used to power a self-lacing mechanism.

Energy from exercise

Energy floors

Rotterdam-based company Energy Floors uses an electromechanical system to turn kinetic energy into electricity. Its Sustainable Dance Floor uses the movement of dancers to light up the ground beneath their feet. The interactive light show was designed to raise awareness of the potential of kinetic energy, and has proved popular for corporate and public events, but they have since developed a new product with more practical benefits. Their Sustainable Energy Floors are designed for areas with high footfall, such as shopping malls, sports arenas and airports. Each step onto a tile can generate between two and 20 joules of energy, which can be used to power nearby lights or signage.



Charge your phone with your clothes

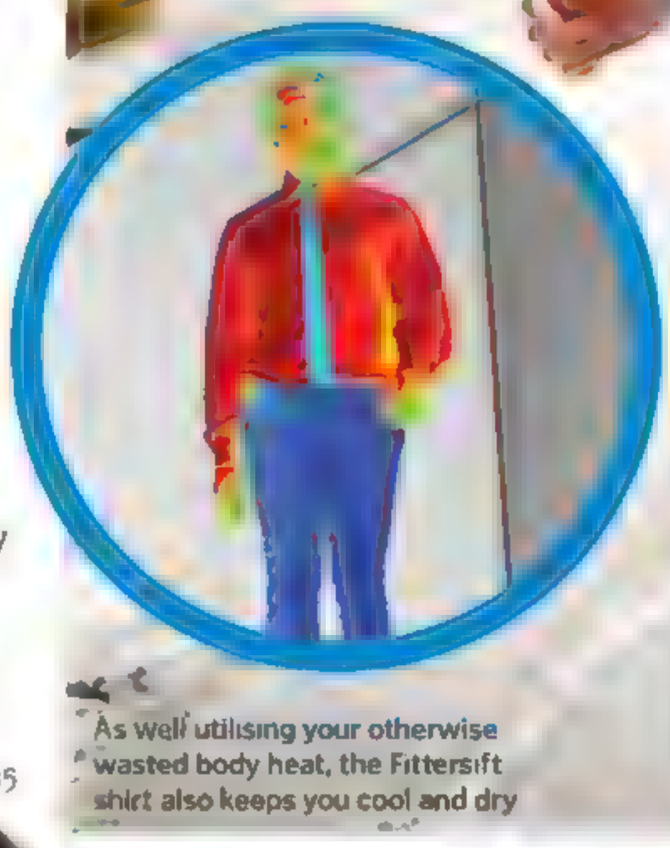
Smart fabrics and other heat-powered innovations

60 per cent of the energy we consume through calories escapes as heat, but rather than wasting this abundant power source, new technology can help us put it to good use.

A team of scientists at Wake Forest University in the United States have developed a thermoelectric fabric called Power Felt that converts heat into electricity and could one day be used to make clothes. Thermoelectric materials have been around for a while, but they are usually brittle and expensive. However, Power Felt is a lightweight, flexible material and is cheap to produce. When placed between two objects with differing temperatures, such as your warm body and the cool air, the electrons in the heated side of the fabric move faster, travelling toward the cooler side. This causes the cold side to become negatively charged and the hot side to become positively charged, creating a voltage that is conducted by the tiny carbon nanotubes within the fabric to generate an electric current. One square centimetre (0.16 square inches) of Power Felt can generate one milliwatt of electricity, so if you lined your phone case with it, it could boost the battery while just sitting in your pocket.

Another type of body heat-powered fabric can be found in the Fittersift dress shirt, which is infused with 13 thermo-reactive minerals that convert body heat that would otherwise be wasted into a usable energy source. The shirt reflects the infrared radiation back toward the body, helping to increase blood oxygen levels, improve circulation and regulate body temperature.

Although these materials are still in development, Stockholm Central Station is already being used to harvest body heat as a power source. The building's ventilation system contains heat exchangers that convert excess heat generated by its 250,000 daily visitors into hot water. This hot water is then pumped into the heating system of a nearby office building, keeping it warm and reducing the energy bill by up to 25 per cent.



As well utilising your otherwise wasted body heat, the Fittersift shirt also keeps you cool and dry

Solar-power clothing

The Solar Fiber project is open-source, to help communicate the potential of solar textiles

Photo: Bas Berends / Model: Daisy van Loenhout

Photo: Brian Smeulders / Model: Stephanie Samson

© Simone Becchetti, Rex Features

"Jellyfish lake is just one of about five Palauan lakes inhabited by these glutinous beauties"

The creatures of Jellyfish Lake

Dip below the calm surface and discover a group of gelatinous wonders

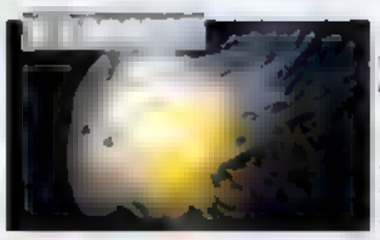
Found off the coast of Koror, Palau in the Philippine Sea, a rocky island uninhabited by humans is host to a colossal colony of jellyfish. The Ongeim'l Tketau marine lake, more commonly known as Jellyfish Lake, is just one of about five Palauan lakes inhabited by these glutinous beauties. The lake itself is an average of 30 metres (98 feet) deep and is connected to the sea by cracks and fissures in the rock.

The unusual chemical parameters of the lake mean it is highly stratified. The uppermost 'layer' of water is rich in oxygen, but around 15 metres (49 feet) beneath the surface the anoxic bottom layer begins – an oxygen-depleted zone high in hydrogen sulphide that makes the depths of the lake a no-go area for scuba divers.

However, swimming in the top layer is permitted – and recommended – as the whole water body is teeming with both golden jellyfish and moon jellyfish species. Neither species' stings are dangerous to humans.

These fascinating animals are able to grow to such large numbers as the lake provides a safe, enclosed ecosystem with very few natural predators. However, there is one sea anemone species living in the lake that has a definite taste for a jellyfish supper.

Every day, an epic migration can be witnessed within the lake, as the jellyfish move to the eastern side of the lake in the morning and then back west again in the evening, tracking the progress of the Sun. It's thought that this daily migratory behaviour helps the jellyfish avoid the shady shoreline areas where the jelly-hungry anemones can be found lurking in wait for an easy meal.



Lion's mane jellyfish
This leviathan can reach up to 2.4m (8ft) in diameter, with over 800 tentacles measuring up to 30m (98ft) in length

Upside-down jellyfish
This jelly spends its life with its bell face-down on the seabed and its tentacles splayed out under the sunlight

Box jellyfish
Found throughout the Indo-Pacific, the stingers on these jellies contain one of the most powerful toxins in the world

Jellyfish symbiosis

"Sea otters face a constant battle to maintain their core body temperature and stay alive"

How sea otters stay warm

They eat, sleep, mate and give birth in water, but how do they fight the chill?

It is a universally accepted truth that sea otters are adorable. But did you know the wettest of weasels are extremely hardy little critters too? They live among the kelp forests that grow off the west coast of North America, Alaska and Russia – where the water temperature can be as low as one degree Celsius (33.8 degrees Fahrenheit) – and almost never come ashore. Heat loss in water is 27 times faster than in air of the same temperature, meaning sea otters face a constant battle to maintain their core body temperature and stay alive.

Unlike other marine mammals, otters don't have a layer of insulating blubber to keep them warm in chilly waters. Instead, they rely entirely on their velvety fur. At up to a million hairs per square inch (for comparison, you probably have as many hairs on your entire head), it is officially the densest fur in the world.

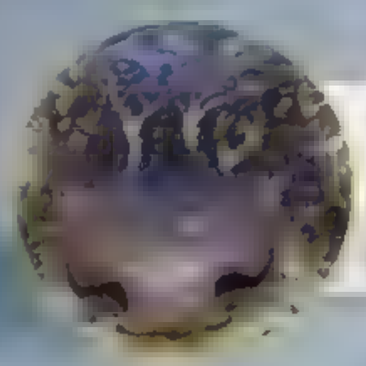
Sea otters' coats are composed of two layers: long waterproof guard hairs and a fluffy underlayer. The guard hairs form a waterproof barrier and are kept oiled with sebaceous secretions from glands in the otter's skin. Bundled around each guard hair are ten to 100 underhairs. These hairs are covered in microscopic barbs that enable the hairs to tangle together and trap a layer of insulating air next to the otter's skin, providing four times the amount of insulation as the same amount of blubber.

At home in the water

Sea otters [illegible]

Spine
A loosely articulated skeleton gives the sea otter the extreme flexibility it needs to obsessively groom every inch of its body.

Skin
Loaded with oil-secreting glands to keep guard hairs in tip-top waterproof condition.

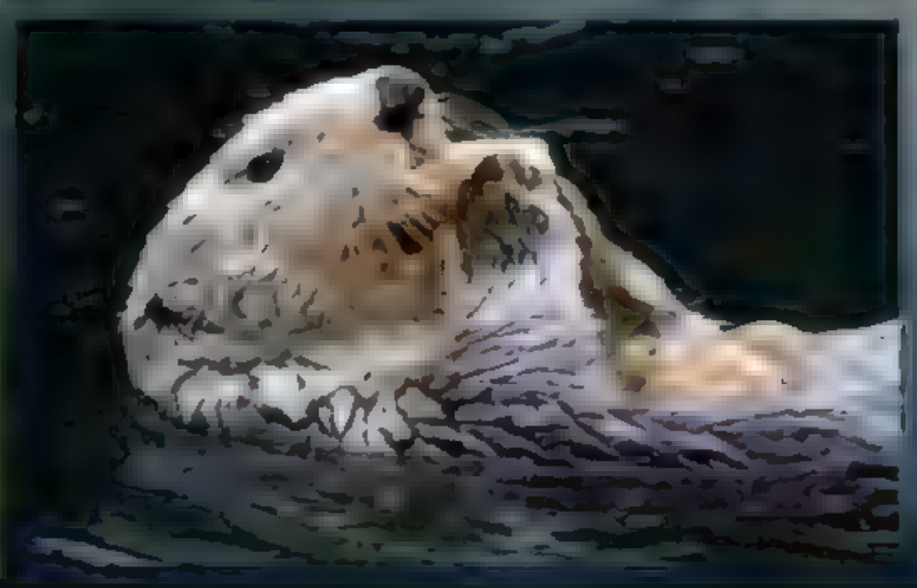


Paw pads
The only part of the body apart from the nose not covered in fur. The sea otter holds these out of the water to minimise heat loss.

Guard hairs
Smooth and waterproof, these prevent cold water from reaching the dense, fluffy undercoat.

Underhairs
Surface texture helps hairs knit together to trap an insulating layer of air next to the skin.

Countercurrent heat exchange
Arteries and veins packed close together in the otter's extremities transfer arterial heat to returning venous blood to conserve body heat.



How does a sea otter spend its day?

Besides their plush fur, sea otters employ another trick to keep themselves warm: they eat an awful lot! Their high metabolic rate – two or three times that of a comparatively sized land mammal – keeps them cosy from within, but means they must consume about 25 per cent of [illegible]

[illegible]

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Save the Children

"It's no secret that dogs have a much better sense of smell than us humans"

What are plant tubers?

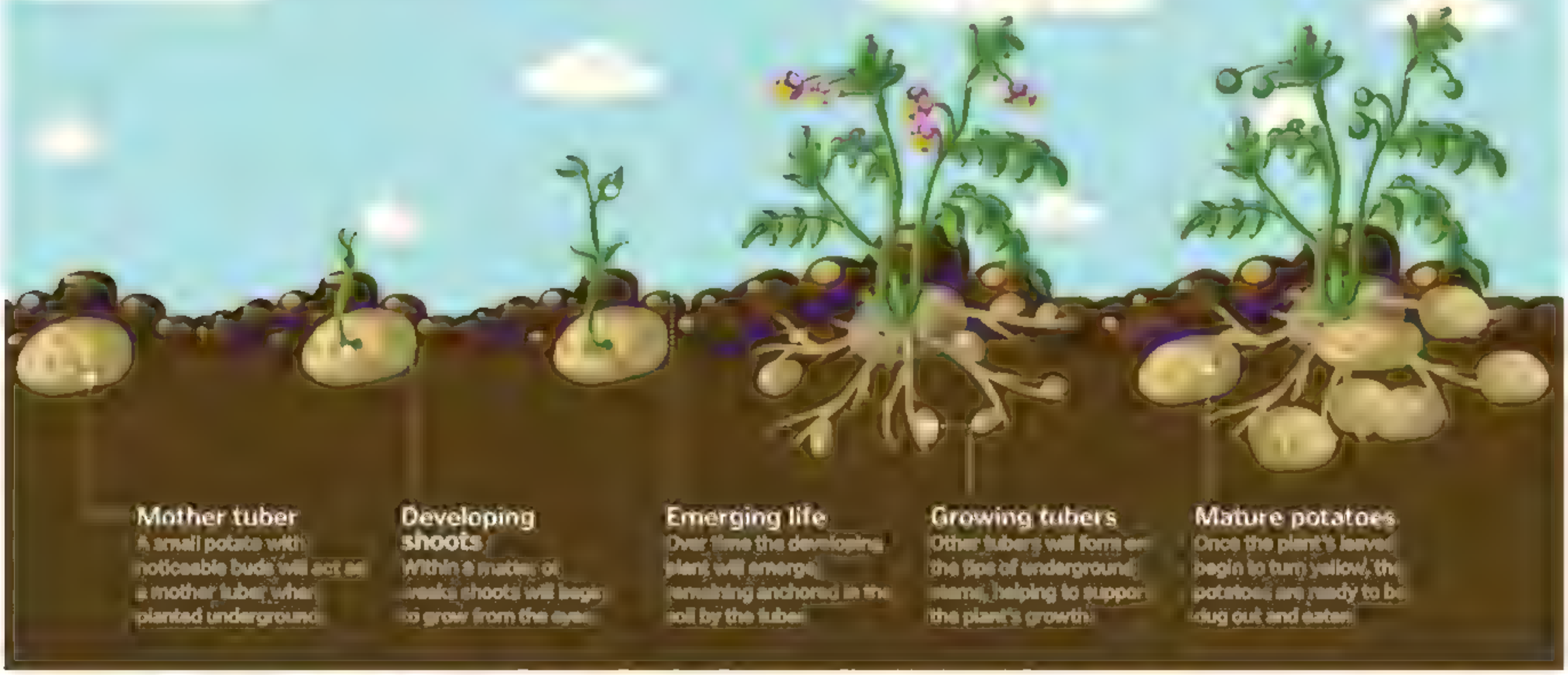
Delve underground and discover the secret to some plant species' survival

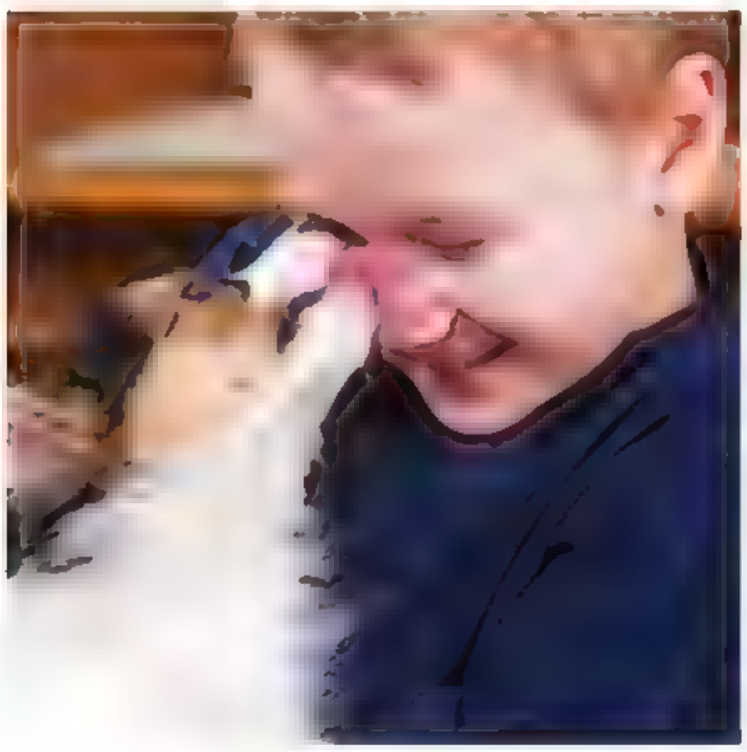
Tubers are unique storage systems that grow on the tips of underground stems. Packed full of vitamins, minerals and nutrients, they supply energy to parent plants that develop above ground, so they can thrive during colds and droughts.

Tubers also play an important role in their species' asexual reproduction, as they are capable of supporting the growth of new stems, even after a parent plant dies off. A good example of this is your average edible potato, which is in fact a tuber. You'll notice if you've ever stored one for too long that buds – or eyes, as they're also known – will begin to sprout from its skin. Underground these buds will mature into new parent plants, which in turn will develop more tubers, ultimately helping to ensure the species' survival.

How tubers work

Discover how these nutrient stores develop





Why do dogs lick people?

Discover what your canine companion is really thinking

Although not scientifically proven, it's widely believed that dogs lick humans as a way of showing affection. That may be true, but there are many other theories that could also explain why they love to lick.

One is that we taste pretty good. It's no secret that dogs have a much better sense of smell than us humans, so just imagine how much information they can collect by licking our skin. Salty sweat and food residue on our palms and faces will not only taste great to a canine companion, but also give them some idea as to where we have been and what we have eaten.

Licking is also considered a learned behaviour. From birth puppies learn that licking is not only a way of keeping clean, but also a way of communicating with other pack members. They will often lick to greet one another, which is known to help strengthen bonds within the group. In adult dogs, licking is also a way of showing submissiveness to a dominant pack member, so it's likely that dogs lick us for the same reasons.

RECORD BREAKERS
SUPER SEED

30kg

LARGEST SEED IN THE WORLD

The coco de mer, a palm tree native to the Seychelles archipelago, produces the largest seeds in the world and can reach over 30cm (12in) in length and 30kg (66lb) in weight.

Did You Know? A date palm seed estimated to be around 2,000 years old [illegible] grown into a plant

The formation of ocean dead zones

The incredible biology behind how and where these barren expanses of ocean occur


The La Jolla 'red tide' of algal blooms off the coast of San Diego has a harmful effect on other ocean life

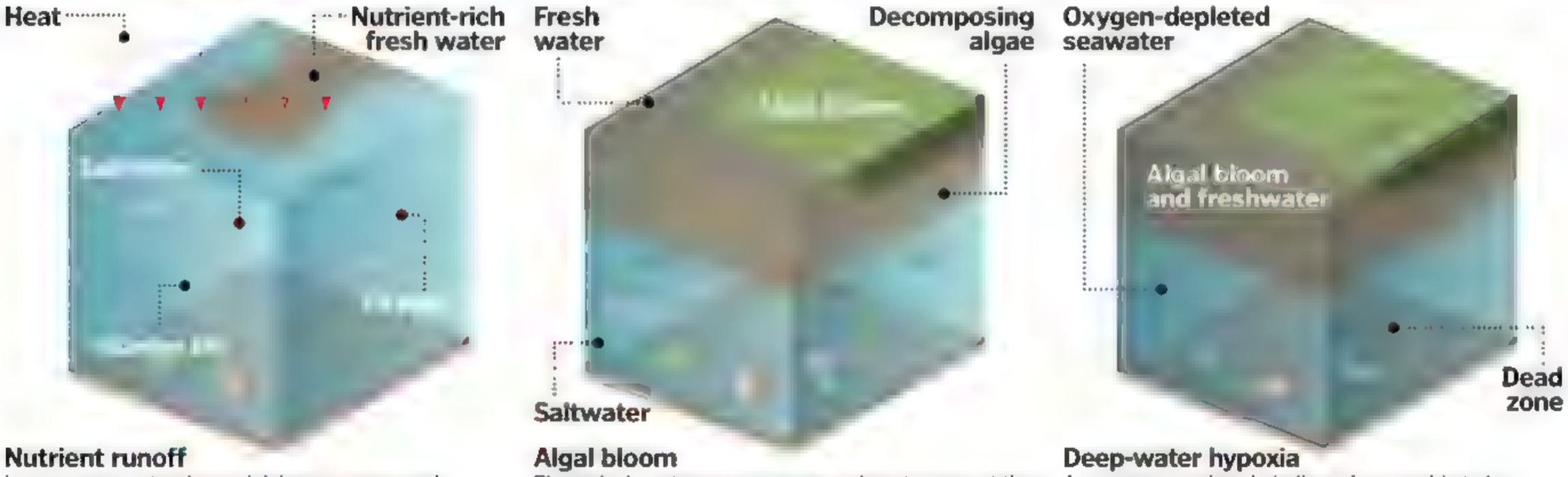
'Dead zones' get their name from the fact that they can support very few plants and animals. This is due to the absence of oxygen, known as 'hypoxia'. Hypoxic conditions can occur in lakes and other standing bodies of water, but also happen in large areas of the ocean.

The main cause of a dead zone is eutrophication – when minerals, usually from agricultural origin, are washed into the water. The heightened nutrient levels stimulate huge blooms of algae on the surface of the water; this then stops any oxygen from making its way into the water and effectively smothers everything living beneath it.

Due to the agricultural nature of the nutrient runoff, dead zones often appear close to the shore. There are around 146 coastal dead zones known around the world, the largest ones being in the Baltic Sea and the Gulf of Mexico.

Becoming a dead zone

How a healthy patch of ocean changes into a hypoxic watery wasteland



Nutrient runoff
In areas near estuaries and deltas, sun-warmed freshwater runs off the land. The nutrient-loaded water sits on top of the seawater and cuts off the oxygen supply to organisms below.

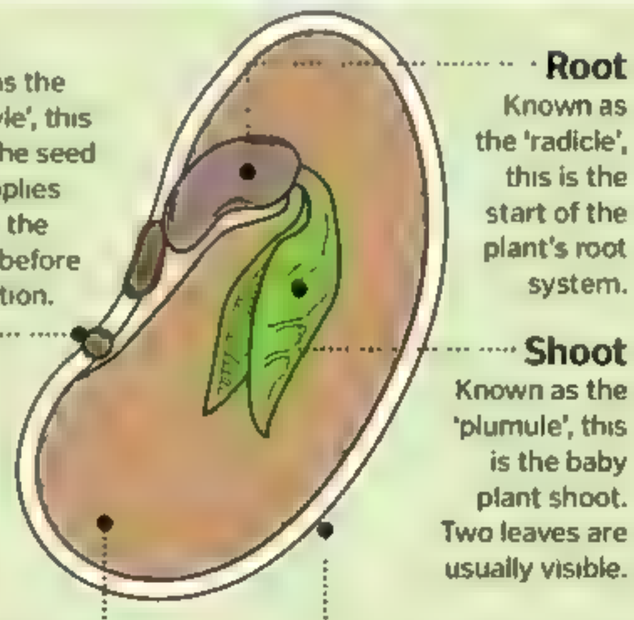
Algal bloom
The spike in nutrients encourages algae to grow at the surface that prevents oxygen transferring to the water beneath. Dead algae also decompose at depth, which uses up oxygen supplies.

Deep-water hypoxia
As oxygen supplies dwindle and are unable to be replaced, the organisms living below are unable to survive. Fish can die in shoals and dead matter floats to the surface.

Inside a seed

These tiny pods contain the potential to become the largest redwood or the prettiest peony

Seeds are the reproductive body of types of plants known as 'angiosperms' – that's the flowering plants – and 'gymnosperms' – the group that contains conifers. Every plant seed, regardless of size or species of its parent plant, contains three main parts: the embryo, the cotyledon and the seed coat. The embryo is the baby plant, the young root and shoot that has the potential to grow up and become the majestic specimen that its parent once was. The cotyledon, or 'food store', is the seed's nourishment and contains enough starchy nutrients for the first few weeks following germination, after which the young plant will be able to make its own food via photosynthesis. The seed coat provides tough protection for the baby plant, enabling seeds to lay dormant over winters, be dispersed by animals, wind or water action and lie in wait until the conditions of light, warmth, oxygen and water are perfect for growth.



Pore
Known as the 'micropyle', this pore in the seed coat supplies water to the embryo before germination.

Root
Known as the 'radicle', this is the start of the plant's root system.

Shoot
Known as the 'plumule', this is the baby plant shoot. Two leaves are usually visible.

Cotyledon
These are actually leaves, attached to the shoot. They supply food and eventually drop off.

Seed coat
Known as the 'testa', this tough outer coating is split open by the root when germination takes place.

"The type of rock in an area greatly affects how the wind shapes it"

How wind erosion works

Learn about how the sheer power of the wind can shape and sculpt whole landscapes

Ever wondered how desert stacks get to where they are, how huge archways appear out of the rock and how colourful stripes stretch along rocky ledges in the desert? All of these are formed by wind erosion – the fancy term for which is Aeolian processes.

In the wide-open expanses of deserts, the sheer force of the wind can eat into softer types of rock, such as sandstone. Particles of rock are removed and lifted up by the wind (this is known as deflation) and then, as the wind blusters its way through the arid landscape, its path governed by the rock formations that dominate the terrain, these particles act almost like sandpaper on the rocks and gradually transform them into the streamlined shapes that follow the wind's path – a process known as abrasion. Over time, this gradual erosion produces the incredible landforms we associate with the desert, which are known as 'yardangs'.

The type of rock in an area greatly affects how the wind shapes it. Softer rock is easily eroded, while harder rock is far more resistant and is likely to be polished by the ferocity of the wind, resulting in smooth, buffed formations. Softer rock is carved out by the wind, producing much more pronounced effects, while a mixture of both hard and soft rock types can produce incredible formations such as buttes and arches.

Monument Valley in Utah, USA is a famous example of extreme wind erosion

Other types of desert erosion

Although the deserts are known for having very little rainfall, the landscape can also be shaped heavily by water action. Rare flash floods are caused by thunderstorms and cloudbursts. The resulting rainwater picks up debris from the desert floor and charges its way through the landscape. The force and action of the water can carve its way through rock, and this is helped by the water's sediment load that, similar to the wind, eats away at the rock in its path. The steep slopes and lack of vegetation in the desert environment means there is little in the way to stop these flash floods tearing through the landscape and making their mark on the desert terrain, carving out canyons and gullies and buffering rocks as they go.

Water flowing through a desert landscape can shape the environment as much as wind erosion

How rock archways are formed

Over time, erosion by the wind helps to hollow out these incredible natural structures

Cracking
Geological processes can cause the rock to crack, creating fissures and exposing the softer layers of rock within.

Overlying rock
The wind gradually erodes the layers of rock above the cracks.

Rain and ice
Rainwater dissolves some of the soft rock's chemical makeup, while water in small cracks freezes and weakens the rock.

Archways widen
Wind erosion continues to wear away at every surface of the exposed archway, constantly widening it.

Collapse
Eventually, the arch is eroded so much that it collapses, leaving two rock pillars standing either side

Rock layers
Different types of rock with different properties form and shape the landscape in layers.

Cracks deepen
As the wind rushes through the cracks they are gradually eroded away and begin to widen and deepen.

Rockfalls
The weakened softer rock begins to crumble and eventually falls away, leaving an arch of more resistant rock.

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FITNESS TECH

How wearables track movement, monitor your heart rate and more

In our technology-saturated society, it's often said we're getting lazier and unhealthier. As it turns out, technology may yet save us from our screen-obsessed selves. Until recently, 'health and fitness tech' generally referred either to gym equipment built to address specific training needs, or to futuristic fabrics designed to improve our comfort (and reduce smelliness!) when engaging in athletic pursuits. That industry still booms today but, more and more, health and fitness tech has come to mean that ever-expanding collection of gadgets and gizmos that help us to dig deeper into our personal fitness data.

Welcome to the 'quantified self' movement. It's the idea that wearable activity trackers and partner apps that log every conceivable aspect of our daily lives – what we eat, how active we are, how well we sleep, and more – might helps us to understand our bodies and ourselves better and be empowered to make choices that improve our health and happiness.

Research shows that habit monitoring is one of the best ways to stick to health goals. But as mere mortals, we're pretty awful at estimating things like how far we've walked and truthfully recalling everything we've eaten in a given day! Today's fitness gadgets quietly log our health metrics and behaviours as we go about our lives, allowing us to study the numbers later and pinpoint areas that need attention.

Not only that, many of the latest products can actually suggest improvements themselves, coaching you on your positioning and technique in sports from football to yoga; making suggestions for how you might get a more restorative night's sleep; or giving you a discreet nudge when you're falling behind on your daily steps target. Elsewhere, social features of fitness apps allow peers to challenge one another, trade recipes and high fives, and offer encouragement. Never has the term healthy competition been more apt.

In the future, we'll likely see even more of these kind of functionalities integrated into our everyday smart devices, as well as our everyday lives; the American Medical Association is in favour of including smart fitness devices in a new model of preventative health care. Today we are the masters of our own fitness destiny like never before. Motivation? There's an app for that!

STOP FACTS
HEALTH APPS

Calorie Counter
1 The world's most popular health and fitness app has a database of over 5 million foods to help dieters keep detailed tabs on what they eat.

Lose It!
2 Based on the principles of calorie tracking and peer support, Lose It! lets users set a daily calorie budget, track food and exercise, and stay motivated to make smart choices.

Sports Tracker
3 It turns a smartphone into a comprehensive sports computer to track times, distances, altitudes, speeds and overall performance for activities including running, cycling, hiking, mountain biking and skiing.

Challenges
4 Motivates users by turning workouts into a huge interactive game where they can compete against friends, take on challenges and earn real-life rewards such as energy bars.

Instant Heart Rate
5 True to its name, this app works by analysing the pulse-induced colour changes in the user's fingertip as they press it to their phone's camera lens.

DID YOU KNOW?

Smart football

Up your game with the ball that coaches you itself

It's the world's first football to offer feedback on your form. The Adidas miCoach Smart Ball looks, feels and handles just like any other top-of-the-line match ball, but it has one huge difference: a 'pit' of sensors suspended at its core records the strike point, speed, spin and trajectory of the ball during dead-ball drills such as penalties and free kicks.

Details of each kick are transmitted in real-time via Bluetooth, to the accompanying iOS miCoach app, which offers tips for how to correct or improve it. The app's library of drill videos makes the ball the ultimate training tool for perfecting tricky techniques – whether that be bending the ball like Beckham or knuckling it like Ronaldo.

Shock-absorbing rods
These press against the ball's inner bladder to keep the sensor package central during impacts.

Graphics
The design helps users line the ball up correctly and acts as targets for different kicks.

Power dock
A wireless induction cradle charges the ball cable-free; a full charge takes about an hour and is good for about 2,000 kicks.

Sensor packet
Includes a six-axis MEMS accelerometer and a magnetometer to track impact, speed, spin and trajectory.

Surface
Thermally bonded synthetic leather in a standard 32-panel, size-5 match-ball layout.

Smart racquet

Become a tennis ace with a racquet that records and rates your returns

If you're serious about your tennis session, you might want to check out the latest offering from the one of the sport's oldest manufacturers. The Babolat Play looks deceptively normal, but a bundle of sensors integrated into its handle tracks all aspects of your game including the number and type of strokes (forehand, backhand, overhead smash or serve); detail about these strokes (whether your forehand slices hit flat or with topspin); where the ball made contact with the string bed; rally duration; swing power and more. Transmitted via Bluetooth to an accompanying app, the data can be used for stroke refinement, post-match analysis or to compete with other aficionados.

Frame
Babolat's GT (graphite tungsten) technology provides excellent stability on ball impact and offers players increased power and precision.

Sensor packet
Includes an accelerometer, gyroscope, vibration sensor and a microprocessor that runs algorithms to select what data to keep.

Memory
Stores up to 150 hours of game data.

Bluetooth/Tag button
Press and hold to transmit match data by Bluetooth; press for less than a second to split a playing session.

Internal mini-USB port
Charge the racquet with a laptop or any USB-enabled charger; download match data to a desktop.

"Basic models will count your steps and track your calorie consumption"

Fitness bands

Leading you by the wrist toward good habits and health

Just a couple of years ago, fitness bands graced the wrists of only the techiest Silicon Valley types, but their mainstream acceptance has been swift, with tens of millions welcoming them as a chance to become more mindful about their daily choices. In fact, sales of fitness bands grew by over 500 per cent between 2013 and 2014. Even the most basic models will count your steps, track your calorie consumption, and communicate this data to an accompanying smartphone app, most commonly via Bluetooth. More advanced versions record the distances you cover, the heights you scale, when you break a sweat, how hard your heart beats, and even how well you sleep. Some even offer helpful suggestions, like alerting you if you've spent too long in the Sun or providing encouragement to hit your goals.

Inside the Fitbit Flex

Getting to grips with this mysterious black band

Wrist strap
Made from lightweight, flexible, durable, waterproof plastic.

Battery
Lithium-ion polymer battery charges in three hours and lasts up to five days.

Motherboard
Where the brains of the Flex live, including an accelerometer and microprocessor.

Light guides
These transmit light as part of the five-LED display.

Bluetooth antenna
Exchanges data with coupled devices, including the Fitbit Flex dongle.

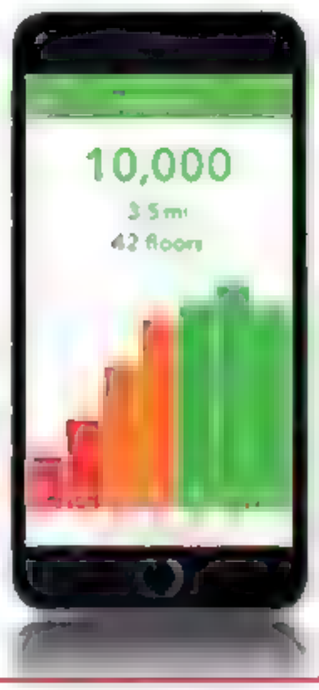
Near Field Communication (NFC) tag
This launches the related Fitbit tracker smartphone/tablet apps with a single touch.

Vibrator
Indicates when you turn different modes on and off or achieve a goal, and acts as a discreet wake up alarm.

Case
It has a rigid plastic skin, with built-in waterproof electrical contacts, to protect components.

Activity

Apps use a variety of different sensors – either within your smartphone or dedicated wearables – to analyse your activity levels. Pedometers are usually based on accelerometer technology and determine the number of steps you take; GPS trackers log the distances you cover; and altimeters measure how much climbing you do – whether that's up the stairs in your home or up the North Face of Everest. Many wearable fitness trackers give extra insight into how hard you're working by recording your heart rate, and some even log your blood-oxygen level – a telltale indicator of respiratory health.



Nutrition

Unlike many health and fitness parameters, which can be tracked automatically by technology we carry or wear, nutrition tracking takes a bit of conscious input from you. Apps such as MyFitnessPal have huge built-in databases of foods. As you log what you eat, the apps break each item down into its nutritional components to give you a detailed picture of your daily diet. To make life a little easier still, some apps let you add dishes you regularly cook at home, others enable you to scan the barcodes of packaged foods, while some even include menus from popular restaurants.

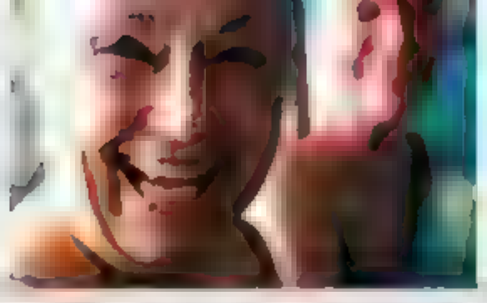
Sleep

Sleep-analysis apps use data about your heart rate, breathing rate and how much you wriggle around, to calculate the hours of sleep you get and what proportion of it is light, deep or REM sleep – the kind where you dream. During deep sleep, for example, your heart rate drops, your breathing slows and deepens, and your body is very still. Sleep data can be collected by various different wearable sensors or devices placed under or atop your mattress. Advanced systems also log ambient conditions such as temperature, light and noise levels to allow you to pinpoint possible sleep saboteurs.

STRANGE BUT TRUE
APP FANATICS

Who are the heaviest users of fitness apps?

A **Young men aged 18-24** B **Mothers aged 25-54**
C **Elderly people aged 75+**



Answer:
Market research company Flurry found that "fitness fanatics" – those who spend more than three times the average amount of time using fitness apps – are mostly mothers aged 25-54, who are sports fans and have very active lives

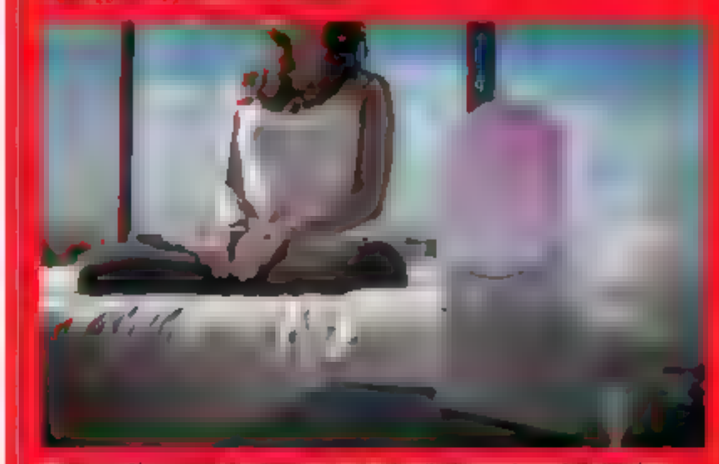
DID YOU KNOW? Some sources trace the concept of the pedometer back to sketches made by Leonardo da Vinci

Blood-pressure monitor

Keep an eye on your blood pressure and keep your doctor in the loop too!

Sleep tracker

Sleep… and wake… smarter by scrutinising your shut-eye!



Smart scales

Get more out of your weekly weigh-in with scales that chart your fitness progress!

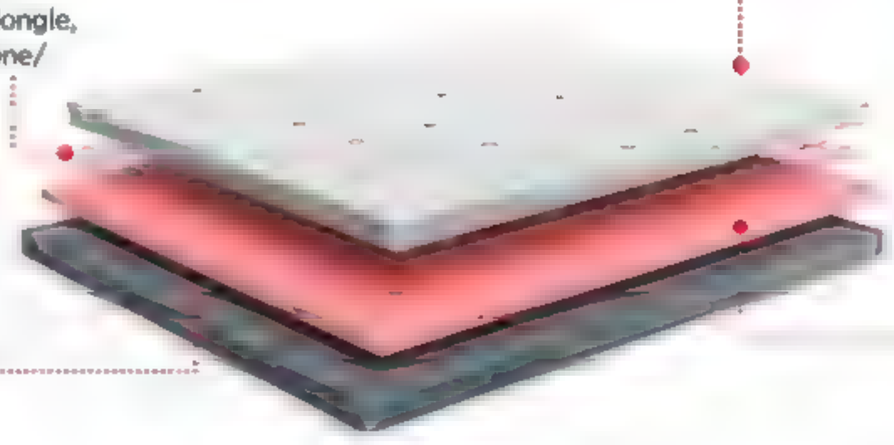
World's first intelligent yoga mat

Forget communing with your inner self and get ready to commune with your yoga mat

SmartMat is a smart, responsive yoga mat that uses an inbuilt array of pressure sensors to study your balance and alignment. Used in conjunction with a smartphone or tablet app, it gives you real-time feedback – voice commands or silent visual tips for when you're in a class. It determines the 'perfect pose' by taking into account factors such as user height, weight, gender and age. This is all part of the calibration process, which includes lying down on the mat so it can determine your Ape Index (ratio and length of torso versus legs). It uses piezoelectric sensors within the mat to measure changes in pressure and forces by converting them to an electrical charge – known as the piezoelectric effect.

Upper interior
Conductive fabric grid allows generated charge to flow as electricity to the tech dongle, which doubles as a phone/tablet stand.

Base layer
Durable, 100 per cent latex-free, flexible, Eco PVC made with SmartGrip Surface Technology to prevent slipping and sliding.



Top surface
Wipe-clean, perspiration resistant, soft-textured surface made from a custom Eco PVC material.

Lower interior
Piezoresistive layer comprising 21,000 piezoelectric sensors that generate electrical charge in response to pressure.

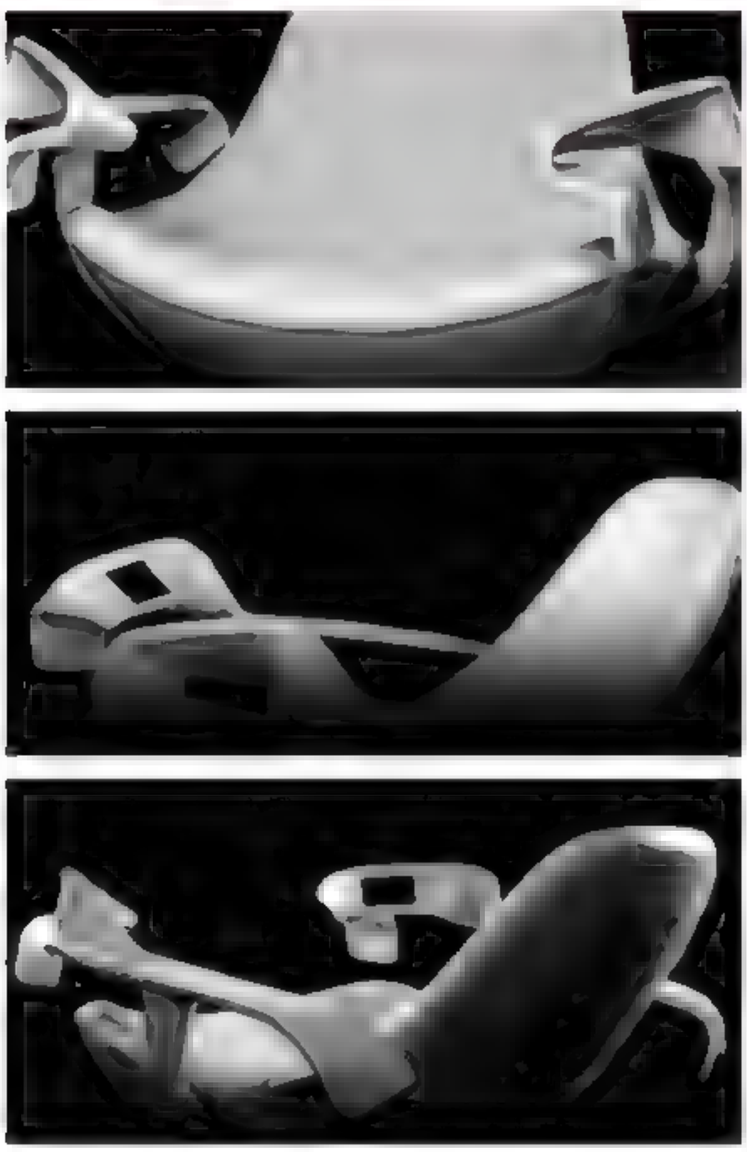
"The outsole – a stretchy elastic webbing – is designed to adopt and move with the foot"

Revolutionary running shoes

Put your best foot forward with today's turbo-powered trainer technology

At the core of Adidas' Ultra Boost trainers are midsoles constructed from thermoplastic polyurethane (TPU) material. This is comprised of thousands of tiny beads, packed together to provide unrivalled springiness and temperature modulation. TPU is said to be more flexible than most air-cushioned trainers, which use ethylene vinyl acetate (EVA) – an elastic substance – and Adidas claim this advanced material offers 20 per cent more energy, boosting the performance of athletes.

The outsole – a stretchy elastic webbing – is designed to adapt and move with the foot, expanding over the duration of a punishing training session. It incorporates Adidas' Primeknit technology, where a single piece of yarn is knitted and attached to the sole of the shoe and then treated with water-resistant polymer. This differs from traditional boots that are stitched to laminate pieces. To top it all, these kicks can supposedly hold up to hundreds of kilometres of pavement pounding. No excuses now.



Exercise while sitting down

Take a seat in your living room's secret gym

Even the most motivated health nut has days where they just can't drag themselves to the gym. To them, and to the couch potatoes of this world, the TAO Chair offers a laid-back alternative: a seated isometric resistance workout that targets the core, upper body and upper leg muscles.

The chair itself looks like something out of a design catalogue. Embedded in its folded ribbons of arms are sensors that monitor the force the sitter generates during grabs, pushes and pulls performed with their arms and legs. Calories burned show on an LCD display, while a companion app guides the workout.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Get a taste of the SmartMat's wake-up routine

www.howitworksdaily.com

DID YOU KNOW?

Fitness gaming

Engage your imagination and watch your workout fly by

Childhood and adult obesity levels have reached epidemic proportions in recent decades, with up to 37 per cent of 11 to 15-year-olds in the UK now classified as obese. A large portion of blame is attributed to the rise in sedentary lifestyles and the proliferation of videogames replacing outdoor play, but game-makers are fighting to turn the tables and make their products a force for good health.

Fitness gaming was arguably sparked by the worldwide craze for Japanese choreography arcade game *Dance Dance Revolution* back in 1998. Companies realised that "gameifying" exercise into physical challenges and group contests engaged that most irrepressible human attribute – the competitive streak – making workouts fun, exhilarating and, best of all, addictive.

Users young and old can get a kick out of racing Mario in the 400-metre hurdles or stepping onto Centre Court to do battle with a global tennis star. These kinds of activities are facilitated by handheld controls and smart play surfaces, with built-in sensors to track players' movements.

Nike+ Kinect Training

Let a virtual trainer put you through your paces and ignite your competitive streak

Partner workout
Connect remotely with friends to work out together and keep each other motivated.

Avatar
Your on-screen representation, extracted by the camera-based Kinect sensor system, lets you see how your movements compare to Coach.

Virtual trainer
Programmed by some of the world's best Nike coaches, it gives you detailed pointers and encouragement.

Counter
This displays info like how many seconds of a drill remain, or how many reps you've completed.

Nike Fuel score
Earn points for form, speed and endurance; compete against a partner or against your own personal best.

Magnetic dumbbells

1 in 10
AMERICAN ADULTS OWN SOME FORM OF FITNESS TRACKER

$50 BILLION
PROJECTED 2018 VALUE OF FITNESS WEARABLES INDUSTRY

54%
OF FITNESS TRACKER OWNERS ARE FEMALE

20 MILLION
FITNESS BANDS SOLD IN 2014

100,000+
HEALTH AND FITNESS TRACKING APPS IN THE APP STORE

14.1%
OF US CONSUMERS USE SMARTPHONE HEALTH APPS

$26 BILLION
PROJECTED 2017 VALUE OF GLOBAL HEALTH AND FITNESS APP MARKET

"The transducer probe is specially designed to create and receive these waves"

How ultrasound scans work

Take a closer look at the science inside this medical machine

An ultrasound is a painless procedure that is used for a number of medical reasons, the most common being to check on the development of a foetus inside the womb.

Ultrasonography works by sending high-frequency sound waves through the body and then measuring their reflected echoes, in order to create a two-dimensional image of internal organs and structures. The transducer probe, which is placed on the skin, is specially designed to create and receive these waves. It does this using a principle called the piezoelectric effect.

Quartz crystals, called piezoelectric crystals, inside the transducer probe rapidly change shape and vibrate once an electric current passes through them. This causes sound waves to be produced, which will then travel freely through fluid and soft tissue inside the body. However, once they reach a denser structure they will bounce back to the transducer as an echo. As a result of this, the crystals inside the probe emit electrical currents, which pass up to the central processing unit (CPU). The information gathered is then processed to form an image on screen.

Ultrasound imaging

Discover how ultrasound is used to look inside the human body

Ultrasound gel
Specialist ultrasound gel is applied to the skin to remove air between the transducer and body. It's used to help spread more sound waves into the body.

Producing an image
The reflected echoes are then passed up to the central processing unit, which calculates the information and produces an image on screen.

Piezoelectric crystals
An electric current causes piezoelectric crystals inside the transducer to vibrate and create sound waves.

Reflecting echoes
Reflected echoes reach the piezoelectric crystals inside the transducer, which causes them to emit an electric current.

Sound waves
Sound waves travel through the body until they reach a boundary between different tissues. Some waves will then reflect back as echoes.

Fuel injection

How does a gas pump know when your tank is full?

Filling up your car's tank with fuel is a common task for millions of motorists, but have you ever wondered how the pump automatically stops when it knows your tank is full? The process is entirely mechanical and begins with a small hole near the tip of the pump's nozzle. This hole allows air to enter a small pipe inside the nozzle, which runs along to the handle of the pump.

When the nozzle is inserted into your car's fuel line and the refuelling process begins, air is sucked into this pipe thanks to a vacuum – known as the Venturi effect.

When the fuel level in the car rises up to the tip of the nozzle, the air in the small pipe is replaced with fuel, which needs a greater suction force to carry it along the pipe. The shutoff mechanism in the handle senses this change in suction pressure and duly closes a valve in the nozzle, blocking the fuel from leaving the pump.

Everything you need to know

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"Some parts of the world are expected to have 5G as early as 2018"

What is 5G?

How the next generation of mobile communication could help to connect us, our homes and our cars

Many of us don't even have access to the 4G mobile network yet, but already the race is on to develop 5G. With demand for mobile data doubling each year, this fifth-generation technology will soon be required to satisfy our ever-increasing need to browse the web and stream online content on our mobile devices. It will also be needed to connect the technology of the future, such as driverless cars, smart cities and the 'Internet of Things' – a network of everyday objects that communicate with each other to make our lives easier.

Although some parts of the world are expected to have 5G as early as 2018, the technology behind it hasn't actually been fully figured out yet. Some companies are looking to build on existing technologies, simply making 4G radio frequencies faster. Others believe the entire radio network will need to be restructured. For example, one promising concept for 5G involves using high-frequency millimetre-waves and a series of base stations connected to buildings and lampposts.

What we do know is that 5G will be incredibly fast. It's expected to be about 100 times faster than 4G, allowing you to download an entire film in under a second. Latency – the time it takes for data to start transferring – will be greatly reduced, meaning the video you want to stream will start instantly when you press play. 5G will also have a much larger capacity, enabling more users to access the network at once and potentially bringing an end to those restrictive data limits imposed my mobile operators.

Of course, your current mobile phone is unlikely to work with any future 5G network, as it will probably need new hardware and software to support it. However, by the time 5G becomes available, you will probably have upgraded your handset anyway and manufacturers are guaranteed to kit out their newer models with the most up-to-date technology.

How 5G could work

Transmitting data from lampposts and cars in the towns and cities of the future

Small base stations
To overcome the short range of the signals, lots of small base stations will be needed to pass on the radio waves of larger masts and dodge buildings.

Personal connection
Each base station would contain hundreds of antennas packed together, potentially one for each nearby mobile device.

Supply and demand
The base stations could also share data between themselves, working out how much each user needs and distributing it accordingly.

Shorter reach
Higher-frequency waves don't travel as far and struggle to pass through buildings, causing a signal drop.

Learn more

To keep up to date with the latest developments in 5G mobile communication, visit **www.5g.co.uk**. The website will be updated with news, guides and events as new information on the tech becomes available.

KEY DATES

PHONING IT IN

1979
The first commercially available cellular network (1G) is introduced by NTT in Japan and uses analogue signals.

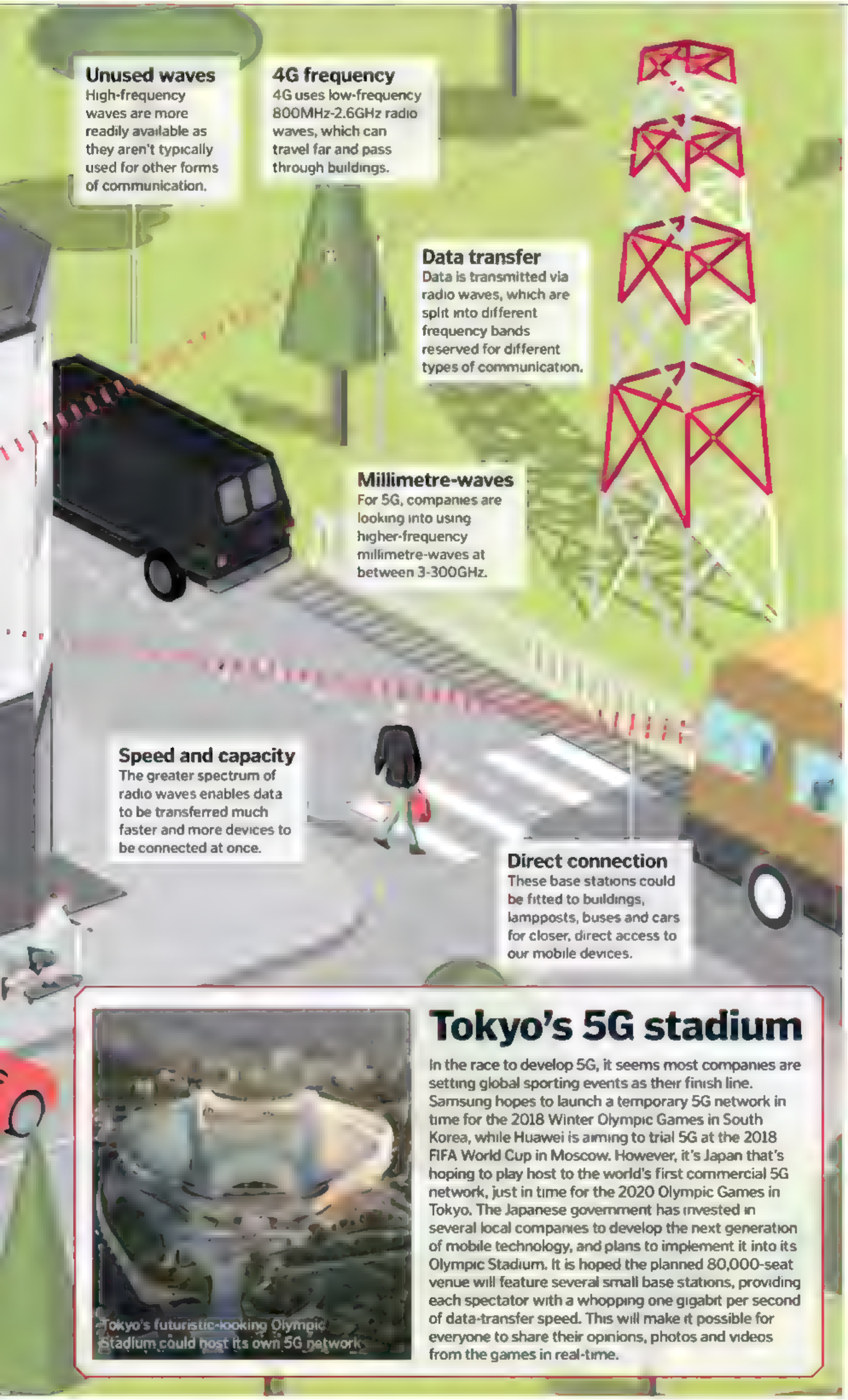
1991
As well as calls, 2G digital cellular networks also support text messaging, and later multimedia messaging and basic internet services.

2001
Using completely different radio frequencies, 3G features higher data transfer rates, enabling you to surf the web and stream music.

2009
4G systems, including LTE (Long Term Evolution) and WiMAX offer speeds similar to that of most home internet connections.

2020
5G is expected to arrive in 2020, but South Korea is racing to introduce it by the 2018 Winter Olympics.

DID YOU KNOW?



Tokyo's 5G stadium

Tokyo's futuristic-looking Olympic Stadium could host its own 5G network

In the race to develop 5G, it seems most companies are setting global sporting events as their finish line. Samsung hopes to launch a temporary 5G network in time for the 2018 Winter Olympic Games in South Korea, while Huawei is aiming to trial 5G at the 2018 FIFA World Cup in Moscow. However, it's Japan that's hoping to play host to the world's first commercial 5G network, just in time for the 2020 Olympic Games in Tokyo. The Japanese government has invested in several local companies to develop the next generation of mobile technology, and plans to implement it into its Olympic Stadium. It is hoped the planned 80,000-seat venue will feature several small base stations, providing each spectator with a whopping one gigabit per second of data-transfer speed. This will make it possible for everyone to share their opinions, photos and videos from the games in real-time.

5G plans

Why is there a need for 5G?

What problems need to be overcome in developing 5G?

What will be the main benefits of 5G?

© Zaha Hadid Architects

"Inventor Alfonso Bialetti was said to be inspired by observing his wife doing laundry"

How a moka pot works

The simple but ingenious design that brought barista-style coffee into every home

The moka pot, also known as a stovetop espresso maker, uses basic physics to achieve a perfectly brewed cup of coffee. It consists of three chambers; one for water, one for the coffee grounds and one for the finished blend.

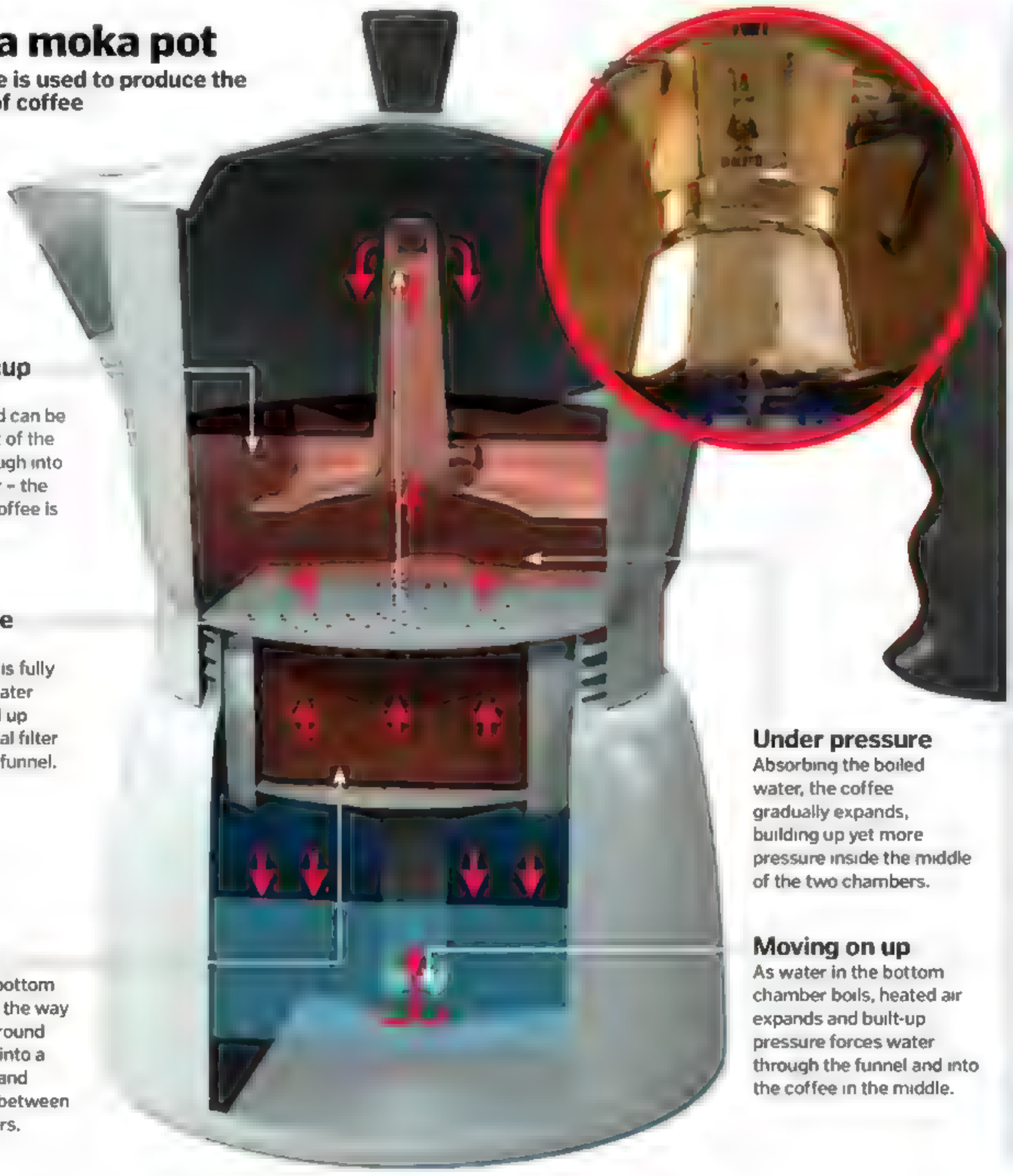
When the moka pot is placed on the stove, the water heats up and generates steam. This increases the pressure in the bottom chamber and pushes the water up through the coffee granules and into the top chamber where it is ready to be poured.

The pressure built up in the pot's chambers reach only 1.5 bars, nowhere near the nine bars achieved in traditional espresso makers. Nevertheless, the simplicity of its design and ability to produce quality cups of coffee made it a hit in households.

It was invented in the 1930s by Alfonso Bialetti, who was said to be inspired by observing his wife doing laundry. Their primitive washing machine consisted of a bucket of soapy water that was brought to the boil over the fire. The water was pushed out of the tube and onto the dirty clothes. Bialetti developed a similar technique for the coffee pot and his design remains much the same to this day. Since its first release in 1933, over 300 million pots have been sold around the world and it remains a staple among coffee enthusiasts everywhere.

Inside a moka pot

How pressure is used to produce the perfect cup of coffee



Time for a cup
A characteristic sputtering sound can be heard as the last of the water boils through into the top chamber – the signal that the coffee is ready to serve.

Escaping the chamber
Once the coffee is fully saturated, the water continues to boil up through the metal filter and into the top funnel.

Preparation
After filling the bottom chamber part of the way to the top, the ground coffee is placed into a separate cradle and screwed tightly between the two chambers.

Under pressure
Absorbing the boiled water, the coffee gradually expands, building up yet more pressure inside the middle of the two chambers.

Moving on up
As water in the bottom chamber boils, heated air expands and built-up pressure forces water through the funnel and into the coffee in the middle.

Born out of fascism

Bialetti's pot emerged during Benito Mussolini's regime, when Italy was in a stage of militarisation and its imports and exports were tightly controlled. The bauxite ore necessary for aluminium were native to Italy, and so were favoured by the fascist regime over other imported metals. Accordingly, moka pots were made from this 'national' metal, and so were cheap and quick to produce. Additionally, the Italian invasion of Abyssinia (modern Ethiopia) in 1935 brought with it the African country's rich coffee plantations. This fuelled an already coffee-obsessed country with even more of the precious beans and the patriotic pot was the perfect vessel to cook them in. In the post-war period the pot found international success in Central Europe and the wider Latin world.

Mussolini's regime saw the trade of coffee and metal ores tightly controlled

The science of sleep

Unravelling the mysteries behind insomnia, sleepwalking, dreams and more

We spend around a third of our lives sleeping; it is vital to our survival, but despite years of research, scientists still aren't entirely sure why we do it. The urge to sleep is all-consuming, and if we are deprived of it, we will eventually slip into slumber even if the situation is life-threatening.

Sleep is common to mammals, birds and reptiles and has been conserved through evolution, even though it prevents us from performing tasks such as eating, reproducing and raising young. It is as important as food for keeping us alive; without it, rats will die within two or three weeks – the same amount of time it takes to die of starvation.

There have been many ideas and theories about why we sleep, from a way to rest after the day's activities or a method for saving energy, to simply a way to fill time until we can be doing something useful, but all of these ideas are somewhat flawed. The body repairs itself just as well when we are sitting quietly, we only save around 100 calories a night by sleeping, and we wouldn't need to catch up on sleep during the day if it were just to fill empty time at night.

One of the major problems with sleep deprivation is a resulting decline in cognitive ability; our brains just don't work properly without sleep. We struggle with memory, learning,

STOP FACTS

Falling
1 One of the most common dreams is falling, but the danger is not as real as it seems. We often wake up before we hit the ground in our dreams, but if we don't we will come to no harm.

Flying
2 Some dreamers can take control of their dream experience, a phenomenon known as lucid dreaming. Once you realise you are dreaming you can start to enjoy strange new sensations like flying.

Taking exams
3 Adults often continue to dream about exams long after they have left school, and experience the same kinds of anxious feelings that they did when they were younger

Being chased
4 The fight or flight response is hard-wired into our brains, and another common dream theme is being chased. The pursuer can be anything from a familiar face to a mythical monster

Death
5 Dreams about the death of a loved one can be distressing, but there is absolutely no evidence to suggest humans are capable of predicting the future in their dreams.

Theories of why we sleep

Theory 1

Energy conservation

We save around 100 calories per night by sleeping; metabolic rate drops, the digestive system is less active, heart and breathing rates slow, and body temperature drops. However, the calorie saving equates to just one cup of milk, which from an evolutionary perspective does not seem worth the accompanying vulnerability.

Theory 3

Restoration

One of the major problems with sleep deprivation is a decrease in cognitive function, accompanied by a drop in mood, and there is mounting evidence that sleep is involved in restoring the brain. However, there is little evidence to suggest that the body undergoes more repair during sleep compared to rest or relaxation.

Theory 2

Evolutionary protection

An early idea about the purpose of sleep is that it is a protective adaptation to fill time. For example, prey animals with night vision might sleep during the day to avoid being spotted by predators. However, this theory cannot explain why sleep-deprived people fall asleep in the middle of the day.

Theory 4

Memory consolidation

One of the strongest theories regarding sleep is that it helps with consolidation of memory. The brain is bombarded with more information during the day than it is possible to remember, so sleep is used to sort through this information and selectively practice parts that need to be stored.

planning and reasoning. A lack of sleep can have severe effects on our performance, ranging from irritability and low mood, through to an increased risk of heart disease and a higher incidence of road traffic accidents.

Sleep can be divided into two broad stages, non-rapid eye movement (NREM), and rapid eye movement (REM) sleep. The vast majority of our sleep (around 75 to 80 per cent) is NREM, characterised by electrical patterns in the brain known as 'sleep spindles' and high, slow delta waves. This is the time we sleep the deepest.

Without NREM sleep, our ability to form declarative memories, such as learning to associate pairs of words, can be seriously impaired; deep sleep is important for transferring short-term memories into long-term storage. Deep sleep is also the time of peak growth hormone release in the body, which is important for cell reproduction and repair.

The purpose of REM sleep is unclear; the effects of REM sleep deprivation are less severe than NREM deprivation, and for the first two weeks humans report little in the way of ill effects.

REM sleep is the period during the night when we have our most vivid dreams, but people dream during both NREM and REM sleep. During NREM sleep, dreams tend to be more concept-based, whereas during REM sleep dreams are more vivid and emotional.

Some scientists argue that REM sleep allows our brains a safe place to practice dealing with situations or emotions that we might not encounter during our daily lives; during REM sleep our muscles are temporarily paralysed, preventing us acting out these emotions. Others think that it might be a way to unlearn memories, or to process unwanted feelings or emotions. Each of these ideas has its flaws, and no one knows the real answer.

Over the next few pages we will delve into the science of sleep and attempt to make sense of the mysteries of the sleeping brain. ▶

"As you progress through stage-three sleep, you become much more difficult to wake up"

The sleep cycle

During the night, you cycle through five separate stages of sleep every 90 to 110 minutes

The five stages of sleep can be distinguished by changes in the electrical activity in your brain, measured by electroencephalogram (EEG). The first stage begins with drowsiness as you drift in and out of consciousness, and is followed by light sleep and then by two stages of deep sleep. Your brain activity starts to slow down, your breathing, heart rate and temperature drop, and you become progressively more difficult to wake up. Finally, your brain perks up again, resuming activity that looks much more like wakefulness, and you enter rapid eye movement (REM) sleep; the time that your most vivid dreams occur. This cycle happens several times throughout the night, and each time, the period of REM sleep grows longer.

Growth hormone release
After you fall asleep, the pituitary gland ramps up its production of growth hormone.

How much time do you spend in each sleep stage?

Low temperature
Body temperature falls just before sleep, and is maintained at a lower level throughout the night.

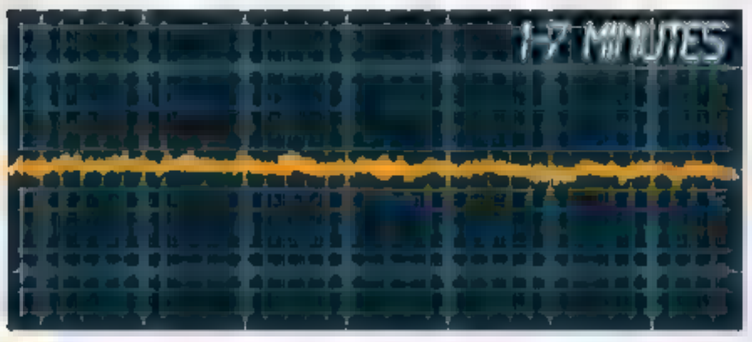
Limited movement
Muscle tone drops during sleep, but you still change position, tossing and turning.

Different when dreaming
During REM sleep, your heart rate rises, but your larger muscles are paralysed; just your fingers, toes and eyes twitch as you dream.

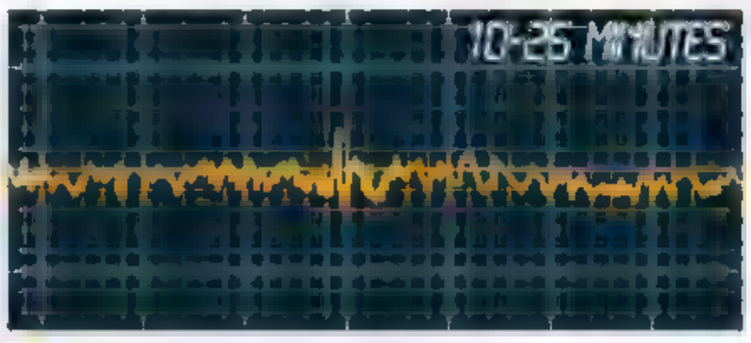
Slow breathing
As you fall into deeper and deeper sleep, your breathing becomes slower and more rhythmic and your heart rate drops.

Stages of sleep

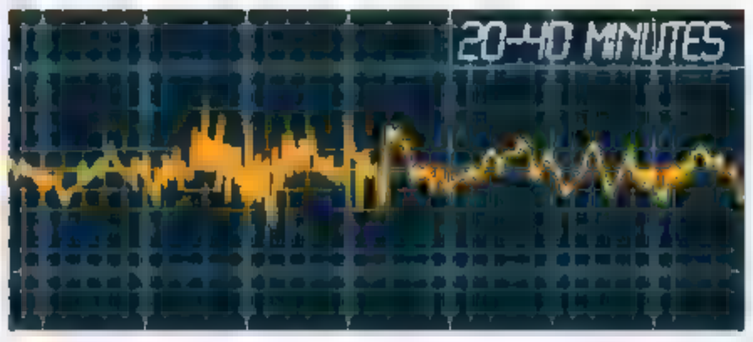
Not all sleep is the same; there are five separate stages, divided up by brain activity



1 Drowsiness
During the first stage of sleep you are just drifting off; your eyelids are heavy and your head starts to drop. During this drowsy period, you are easily awoken and your brain is still quite active. The electrical activity on an electroencephalogram (EEG) monitor starts to slow down, and the cortical waves become taller and spikier. As the sleep cycle repeats during the night, you re-enter this drowsy half-awake, half-asleep stage.



2 Light sleep
After a few minutes, your brain activity slows further, and you descend into light sleep. On the EEG monitor, this stage is characterised by further slowing in the waves with an increase in their size, and short one or two-second bursts of activity known as 'sleep spindles'. By the time you are in the second phase of sleep, your eyes stop moving, but you can still be woken quite easily.



3 Moderate sleep
As you start to enter this stage, your sleep spindles stop, showing that your brain has entered moderate sleep. This is then followed by deep sleep. The trace on the EEG slows still further as your brain produces delta waves with occasional spikes of smaller faster waves in between. As you progress through stage-three sleep, you become much more difficult to wake up.

Tokyo, Japan

According to data collected by the Jawbone UP fitness tracker in 2014, Tokyo is the city that sleeps the least, averaging just five hours and 44 minutes each night.

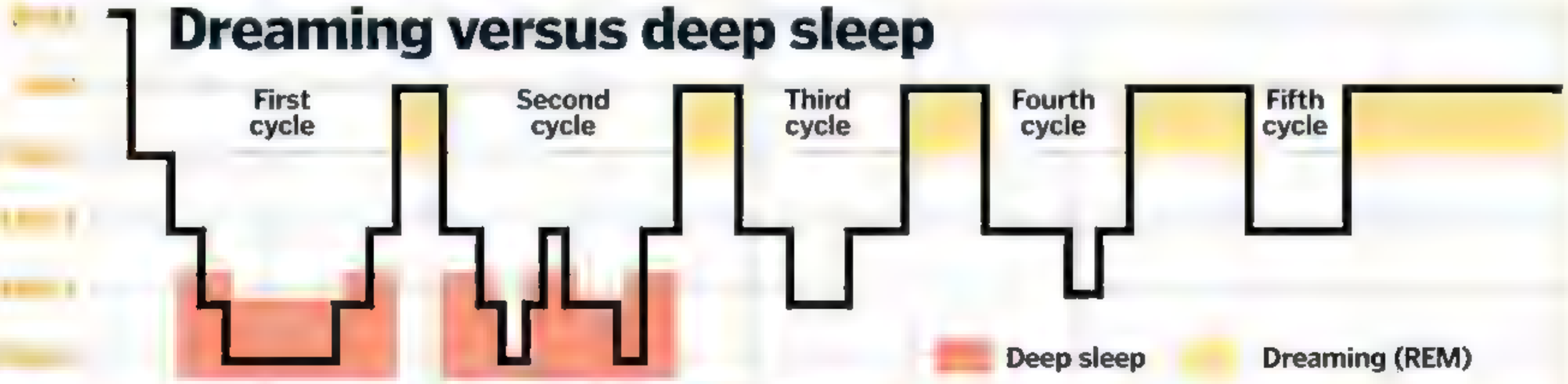
Moscow, Russia

People living in the famous Russian capital sleep in late, rising at 8.08am on average after six hours and 42 minutes of sleep

Melbourne, Australia

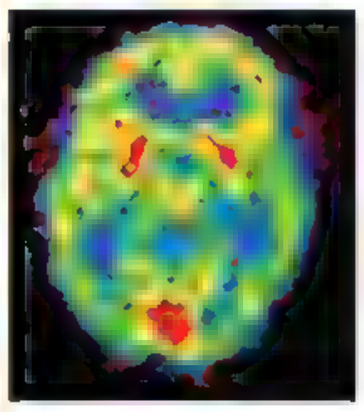
The residents of the Australian city of Melbourne clock an average of six hours and 58 minutes of sleep every night

Dreaming versus deep sleep



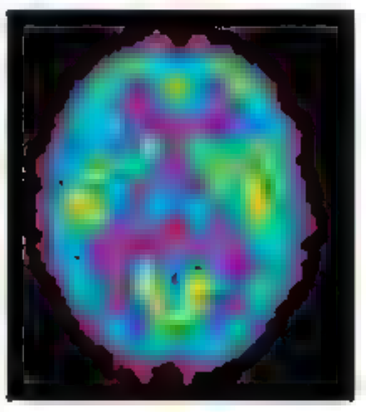
Clearing the mind

Brain activity



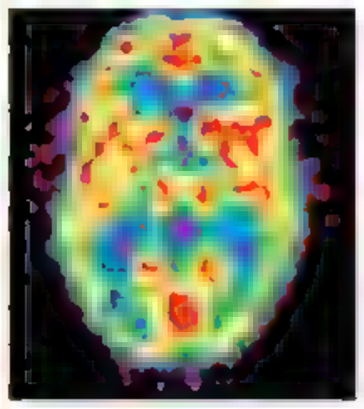
Wide awake

The red areas in this scan show areas of activity in the waking human brain, while the blue areas represent areas of inactivity.



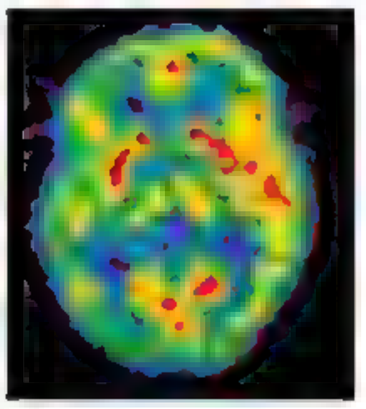
Deep sleep

During the later stages of NREM sleep, the brain is less active, shown here by the cool blue and purple colours that dominate the scan.



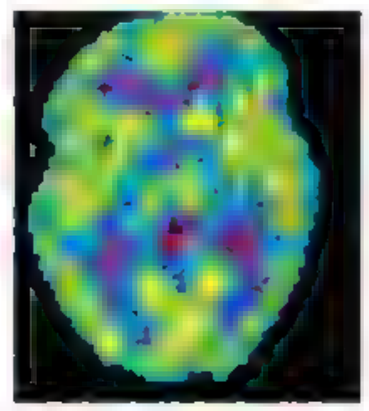
REM (dream) sleep

When the brain is dreaming it is very active, showing similar red patterns of activity to the waking brain.



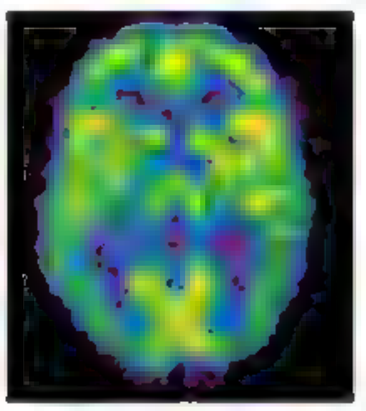
Light sleep

The first stages of NREM sleep, the brain is less active than when awake, but you remain alert and easy to wake up.



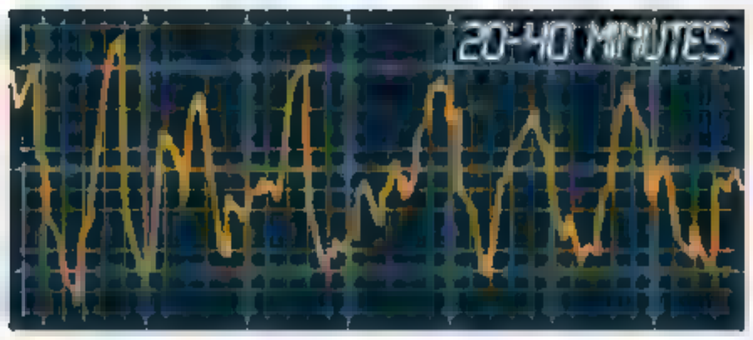
Sleep deprivation

The sleep-deprived brain looks similar to the brain during NREM sleep, showing patterns of inactivity.



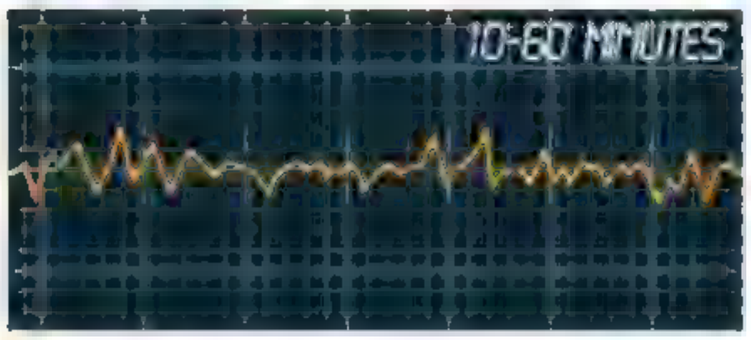
NREM sleep

As you descend through the four stages of NREM sleep, your brain becomes progressively less active.



4 Deep sleep

There is some debate as to whether sleep stages three and four are really separate, or whether they are part of the same phase of sleep. Stage four is the deepest stage, and during this time, you are extremely hard to wake. The EEG shows tall, slow waves known as delta waves, your muscles relax and your breathing becomes slow and rhythmic, which can lead to snoring.



5 REM sleep

After deep sleep, your brain starts to perk up and its electrical activity starts to resemble the waking brain. This is the period of the night when most dreams happen. Your muscles are temporarily paralysed, and your eyes dart back and forth, giving this stage its name, rapid eye movement (REM) sleep. You cycle through the stages of sleep about every 90 minutes, experiencing between three and five dream periods each night.

"Difficulty falling asleep is known as insomnia, and is one of the most familiar sleep disorders"

Sleep disorders

There are over 100 different disorders that can get in the way of a good night's sleep

Sleep is necessary for our health, so disruptions to the quality or quantity of our sleep can have a serious negative impact on daily life, affecting both physical health and mental wellbeing.

Sleep disorders fall into four main categories: difficulty falling asleep, difficulty staying awake, trouble sticking to a regular sleep pattern and abnormal sleep behaviours.

Struggling with falling asleep or staying asleep is known as insomnia, and is one of the most familiar sleep disorders; around a third of the population will experience it during their lifetime.

Difficulty staying awake, or hypersomnia, is less common. The best-known example is narcolepsy; sufferers experience excessive daytime sleepiness, accompanied by uncontrollable short sleeps during the day.

Trouble sticking to a regular sleeping pattern can either be caused by external disruption to normal day-to-day rhythms, for example by jet lag or shift work. It can also be the result of an internal problem with the part of the brain responsible for setting the body clock.

Abnormal sleep behaviours include problems like night terrors, sleepwalking and REM-sleep behaviour disorder. Night terrors and sleepwalking most commonly affect children, and tend to resolve themselves with age, but other sleep behaviours persist into adulthood; in REM-sleep behaviour disorder, the normal muscle paralysis that accompanies dreaming fails, and people begin to act out their dreams.

Treatment for different sleep disorders varies depending on the particular problem, and can be as simple as making the bedroom environment more conducive to restful sleep.

A continuous positive airway pressure (CPAP) machine pumps air into a close-fitting mask, preventing the airway from collapsing

Sleepwalking

Sleepwalkers can perform complicated actions while in deep NREM sleep

Sleepwalking affects between one and 15 per cent of the population, and is much more common in children than in adults, tending to happen less and less after the age of 11 or 12. Sleepwalkers might just sit up in their bed, but can perform complex behaviours, such as walking, getting dressed, cooking, or even driving a car. Although sleepwalkers seem to be acting out their dreams, sleepwalking tends to occur during the deep-sleep phase of NREM sleep and not during REM sleep.

Sleep apnoea

Sleep apnoea is a dangerous sleep disorder; the walls of the airways relax so much during the night that breathing is interrupted for ten seconds or more, restricting the supply of oxygen to the brain. This lack of oxygen initiates a protective response, pulling the sufferer out of deep sleep to protect them from damage. Sometimes this causes people to wake up, but often it will just put them into a different sleep stage, interrupting their rest and causing feelings of tiredness the next day.

20 hours a day

SLEEPIEST ANIMAL

The little brown bat is the sleepiest animal on the planet, spending a massive 20 hours every day snoozing. The koala is a close rival, sleeping for over 14 hours every day.

Narcolepsy

Narcolepsy is a chronic condition that causes people to suddenly fall asleep during the daytime. In the United States, it affects one in every 3,000 people. Narcoleptics report excessive daytime sleepiness, accompanied by a lack of energy and impaired ability to concentrate. They fall asleep involuntarily for periods lasting just a few seconds at a time, and some can continue to perform tasks such as writing, walking, or even driving during these microsleeps. In 70 per cent of cases, narcolepsy is accompanied by cataplexy, where the muscles go limp and become difficult to control. It has been linked to low levels of the neurotransmitter hypocretin, which is responsible for promoting wakefulness in the brain.

Insomnia

Insomniacs have difficulty falling asleep or staying asleep. Sufferers can wake up during the night, wake up unusually early in the morning, and report feeling tired and drained during the day. Stress is thought to be one of the major causes of this sleep disruption, but it is also associated with mental health problems like depression, anxiety and psychosis, and with underlying medical conditions ranging from lung problems to hormone imbalances. After underlying causes have been ruled out, management of insomnia generally involves improving 'sleep hygiene' by sticking to regular sleep patterns, avoiding caffeine in the evening, and keeping the bedroom free from light and noise at night.

One in three people in the UK will experience insomnia in their lifetime

Sleep studies

Electrodes monitor brain activity, eye movement, heart rate and breathing in sleep studies

"Ensuring you see sunlight in the morning can help to keep your circadian clock in line"

How to get a good night's sleep

Understanding your biological clock is the key to a healthy night's sleep

Your body is driven by an internal circadian master clock known as the suprachiasmatic nucleus, which is set on a time scale of roughly 24 hours. This biological clock is set by sunlight; blue light hits special receptors in your eyes, which feed back to the master clock and on to the pineal gland. This suppresses the production of the sleep hormone melatonin and tells your brain that it is time to wake up.

Disruptions in light exposure can play havoc with your sleep, so it is important to ensure that your bedroom is as dark as possible. Many electronic devices produce enough light to reset your biological clock, and using backlit screens late at night can confuse your brain, preventing the production of melatonin and delaying your sleep.

Ensuring you see sunlight in the morning can help to keep your circadian clock in line, and sticking to a regular sleep schedule, even at the weekends, helps to keep this rhythm regular.

Another important factor in a good night's sleep is winding down before bed. Stimulants like caffeine and nicotine keep your brain alert and can seriously disrupt your sleep, and even depressants like alcohol can have a negative effect; even though it calms the brain, it interferes with normal sleep cycles, preventing proper deep and REM sleep.

The blue light from televisions, mobile phones and computer screens disrupts your circadian rhythm

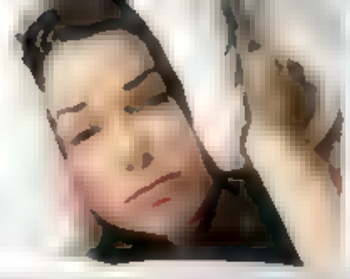
THE DANGERS OF SLEEP DEPRIVATION

Lack of sleep doesn't just make you tired. It can have dangerous, unseen effects

STRANGE BUT TRUE

Who holds the world record for the longest time without sleep?

A Randy Gardner B Barack Obama C No one



Answer:
Randy Gardner used to hold the official world record, set at 264 hours (11 days) in 1964, but today no one is able to claim the title. The Guinness Book of World Records scrapped it in 1989 because trying to break the record is considered too dangerous

Sleep myths debunked

We explain the science behind five of the most common myths about sleep

"COUNTING SHEEP HELPS YOU SLEEP"

This myth was put to the test by the University of Oxford, who challenged insomniacs to either count sheep, imagine a relaxing scene, or do nothing as they tried to fall asleep. When they imagined a relaxing scene, the participants fell asleep an average of 20 minutes earlier than when they tried either of the other two methods.

"YAWNING WAKES YOU UP"

MYTH DEBUNKED

Yawning has long been associated with tiredness and was fabled to provide more oxygen to a sleepy brain, but this is not the case. New research suggests that we actually yawn to cool our brains down, using a deep intake of breath to keep the brain running at its optimal temperature.

"TEENAGERS ARE LAZY"

MYTH DEBUNKED

Sleep habits start to change just before puberty, and between the ages of ten and 25, people need around nine hours of sleep every night. Teens can also experience a shift in their circadian rhythm, called sleep phase delay, pushing back their natural bedtime by around two hours, and encouraging them to sleep in.

"YOU SHOULD NEVER WAKE A SLEEPWALKER"

Many people have heard that waking a sleepwalker might kill them, but there is little truth behind these tales. Waking a sleepwalker can leave them confused and disorientated, but the act of sleepwalking in itself can be much more dangerous; gently guiding a sleepwalker back to their bed is the safest option, but waking them carefully shouldn't do any harm.

MYTH DEBUNKED

"CHEESE GIVES YOU NIGHTMARES"

MYTH DEBUNKED

The British Cheese Board conducted a study in an attempt to debunk this myth by feeding 20g (0.7oz) of cheese to 200 volunteers every night for a week and asking them to record their dreams. There were no nightmares, but strangely 75 per cent of men and 85 per cent of the women who ate Stilton reported vivid dreams.

SLEEP STATS

"Patients are carefully screened before undergoing hair transplantation, similar to cosmetic procedures"

The truth about hair transplants

How this surgical technique battles baldness

Male pattern baldness is common, although in some people it can lead to concerns over appearance and even a severe loss of confidence. Most choose to accept it, but others are fighting the balding process. Modern science has recently updated ancient techniques, meaning that hair transplants can now reliably restore normal hair patterns.

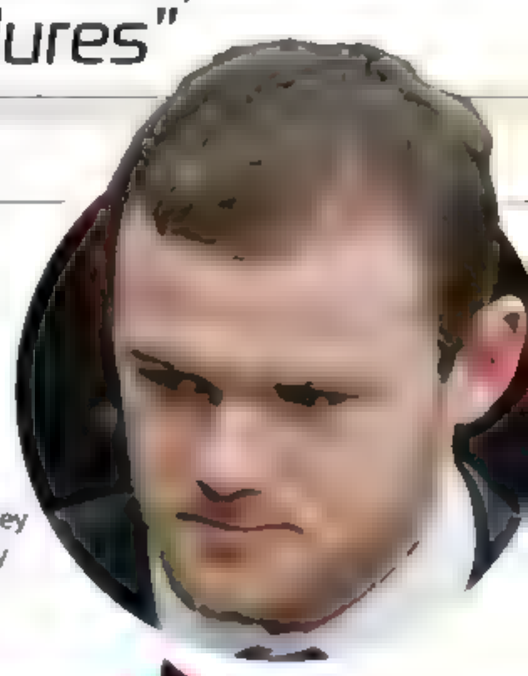
Patients are carefully screened before undergoing hair transplantation, similar to patients before any cosmetic procedures. While hair transplants can restore self-confidence, it's important that they aren't used to fix problems in patients' lives that can't be solved through a change in appearance alone.

Hair transplants have been practiced as far back as the 19th century. However, it is only in the last 20 years that modern techniques have led to reliable and realistic results. Currently, two techniques are used the most. The first involves taking a thin strip of hair from the back of the scalp, removing the hair follicles and implanting them to the front of the hairline. The second doesn't involve removing a strip; rather, small units of two to four follicles are removed and then transplanted in the required area.

These techniques have become so sophisticated that the direction of the hair follicle is controlled when implanting it in the new site. This gives a natural hair-growth direction and a realistic pattern. These procedures aren't without risks, though. They can be painful, and as with any surgical wound, infection can set in. There is also no guarantee of success as baldness can recur. However, it is a generally successful procedure and can restore lost confidence.

How to perform a hair transplant

The basic steps in performing a strip harvest of hair, the most commonly used method



Footballer Wayne Rooney has famously had a hair transplant

STOP FACTS

Women at risk

1 Although baldness in women is less common, 13 out of 100 women before and 75 out of 100 after the menopause experience excess hair loss.

Patterns

2 Someone has even made a chart of the most common patterns of male pattern baldness. Check out the so-called Norwood scale online.

Medicines

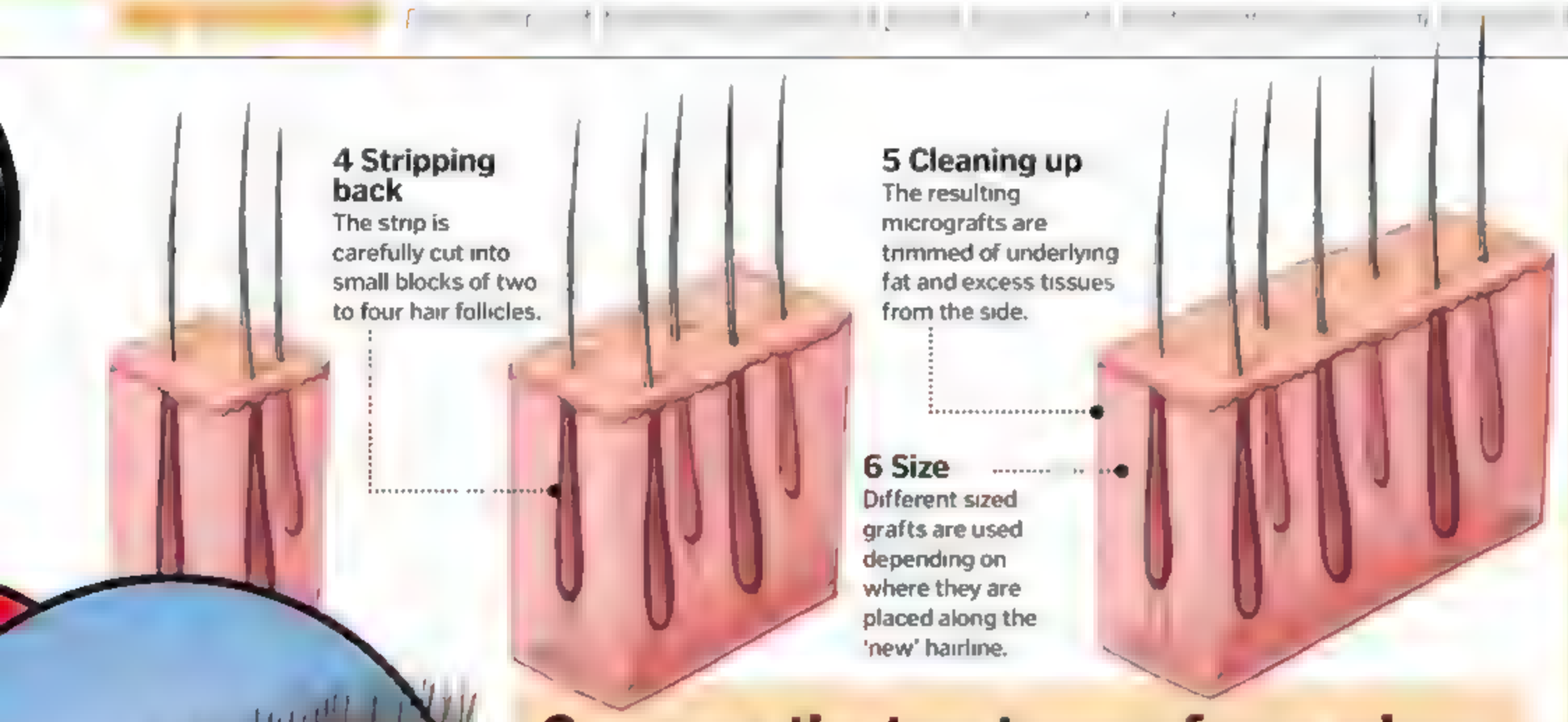
3 Minoxidil is one of the most popular medicines for hair loss, but scientists still aren't sure how it works; it was noticed as a side effect when used to treat high blood pressure!

Hair loss is normal!

4 Most people lose around 100 hairs per day. Since the average scalp has 100,000 growing and regenerating hair follicles, you don't notice.

Sign of other disease

5 95 per cent of baldness is hereditary, but some is a sign of underlying disorders, such as hormone imbalances, reaction to medications, or physical and emotional stress.



Compare the two types of procedure

The two most common techniques are strip harvesting and follicular unit extraction (FUE). Strip harvesting involves a strip of skin and hair is surgically removed from the back of the scalp. Although it is successful and fast, it requires a general anaesthetic and leaves a small scar.

FUE is done under local anaesthetic takes longer; sometimes two to three treatments are needed on separate days. Individual hair follicles are stripped out using a special device and then are implanted in the front of the scalp. There is no resulting scar or need for general anaesthetic, and it is very precise.

How hair is lost

The most common type of baldness is male pattern baldness, which can affect 50 per cent of men over the age of 50. Typically, the hair on the temples thins while the hair on the top of the head recedes. It usually takes around ten years for the hair to recede fully, leaving a small rim around the sides and back.

Changes in signalling of the male sex hormone dihydrotestosterone (DHT) is primarily responsible. The hairs on the head become susceptible to it, which causes thinning and then hair loss. Why the chest or beard hair isn't affected is unknown. This type of age-related baldness can affect women too, but is less common.

Different types of hair loss also exist. These include patchy hair loss on the scalp (leaving tufts), loss of all body hair (head, chest, arms and legs), and universal hair loss (all hair including eyebrows and eyelashes).

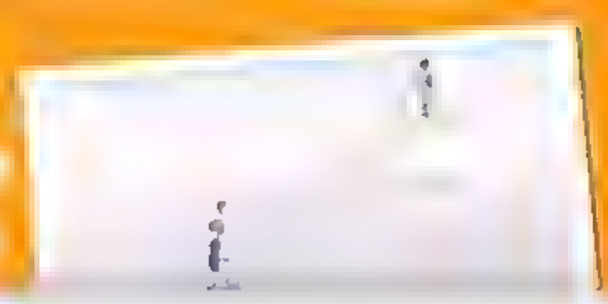
Hair transplant science has improved greatly in the last 20 years

"When light passes through the crystals, it refracts, allowing it to pass through the filters at different angles"

Crystallised alcohol

The hidden beauty of our favourite alcoholic drinks

If you leave a drop of an alcoholic beverage, to dry out, the water and alcohol will eventually evaporate to leave behind crystallised sugar. If you then look at this sugar through a polarising microscope, you will see a pattern of bright colours as light refracts through the crystals. The effect is created using two polarising filters, one between the crystals and the light underneath them, and another positioned at a 90-degree angle from it, between the crystals and the microscope lens above them. As these filters force light waves to oscillate in one direction, rather than all different directions as they would normally, the two polarising filters should block the light completely. But when the light passes through the crystals, it refracts, allowing it to pass through the filters at different angles so we see lots of vibrant colours. Geologists use the same technique to study the structure and composition of rocks.



Cricket-ball physics

In a game of fine margins, physics can make all the difference

The movement of a cricket ball is unique within the sporting world. When the ball is delivered, a layer of air known as a 'boundary layer' forms over the ball. This is where the physics come into play. By angling the seam – the stitched part in the middle – the bowler can alter the pressure of the forces on the ball and choose which way the delivery will go. The aerodynamics can be varied further by the bowler changing the pace of the ball and where the ball bounces. These deliveries are known as 'cutters' to cricket fans and the practice is called seam bowling. Spin is another weapon in the bowler's armoury. Spin bowlers use their wrist or fingers to put revolutions on the ball to allow it to spin fiercely once it has pitched. Slow spin works better on dry and dusty pitches where the ball can skip off the pitch.

Side forces also act on the ball in swing bowling. When one side of the ball becomes rougher than the other, that half becomes less streamlined. Bowlers frequently use this to their advantage to move the ball sideways in the air in order to confuse batsmen into playing false and poorly timed shots. The effect of swing can be exaggerated even further by shining one side of the ball, although using anything other than your cricket whites to rough the ball up is considered unsporting.

Cricket physics

From the moment it is released, strong forces work upon the little red sphere

Movement through the air
When the ball is airborne, the stitched seam and the smooth and rough sides create air pockets that make it move unpredictably.

Boundary layer
This thin layer of air surrounds the ball as it travels. This is when the forces begin to act upon the ball.

Grip
The bowler's grip can determine how spin, swing and seam act on the ball upon delivery.

Rough side
The rough skin makes the airflow more turbulent on this side.

Seam position
The stitching is essential for good seam bowling that moves off the pitch once it has bounced.

Delivery stance
The ideal delivery stride for a bowler is to be upright, causing as little strain on the back as possible.

Backspin and slower balls
A useful trick in the bowler's armoury, the slower ball can deceive the batsman.

Smooth side
In conventional swing, the shiny side allows air to flow smoothly around it.

Pace and bounce
Swing can be achieved by some bowlers at lower speeds, but for most, it is only possible at around and above 135km/h (84mph).

The mystery of reverse swing

James Anderson is England's premier swing bowler, making the ball reverse swing at high speeds

© Getty; Thinkstock

NEXT-GEN EMERGENCY VEHICLES

We reveal the latest tech to help pursue lawbreakers, extinguish infernos and save lives

Maintaining law and order can be a tough test so having top-notch technology to back you up is essential. Both the current and upcoming generation of emergency vehicles contain state-of-the-art kit that performs a variety of functions, whether aiding in the pursuit of criminals, dampening flames or preserving life.

From unmanned drones, to futuristic ambulances and high performance police Interceptors, the technology at the disposal of the emergency services is extremely sophisticated. Take the Oshkosh Striker fire engine, for example, which can pierce up to 142 centimetres (56 inches) of metal in order to access blazing infernos. Ambulances are also being revamped with the aim to kit out the vehicles with tools and apparatus that will be on par with the best a hospital can provide. Saving lives on the scene of an incident could become the norm in the near future.

Vehicles such as the Striker put efficiency and quality above everything else, while in Dubai police supercars are seen as the way forward. In the United Arab Emirates' largest city, everything is larger than life, and the police Lambos and Ferraris you see roaming the streets are no different.

Today's emergency services are also embracing less typical ways of maintaining order than before. Unmanned aerial vehicles (UAVs) are already making an impact in the world of policing, allowing for new and effective ways of tracking offenders from the skies. The Stealth motorcycle is another vehicle that moves away from the traditional methods of policing by accessing both crowded areas and off-road locations with ease.

All of the emergency departments are finding ways to make the daily routine safer, simpler and more efficient. To see just how these new vehicles will revolutionise public safety, How it Works is getting under the bonnet of the emerging cars, trucks and bikes available to the emergency services. The future is now.

Interceptor Sedan Flex Fuel
With 210km/h (130mph) to play with, the Sedan can pursue lawbreakers across the city and the country at high speeds

Interceptor Utility
Despite having the same top speed, the Utility boasts superior torque and horsepower as well as an all-wheel-drive system

Interceptor Sedan EcoBoost
The fastest of all the Interceptors can reach speeds of 238km/h (148mph), but still marks very highly in fuel economy

Inside an ambulance

How the ambulances of the world are the safest and best equipped they've ever been

The role of an ambulance isn't just to transport patients to hospital. Now, the vehicle must be capable of accessing remote areas and treating patients effectively on the go. Paramedics have the equipment to assess and treat the injured on the scene and while the vehicle is on the road. This gives the patient the best chance of survival even before entering the hospital ward.

Current ambulances come fully loaded with defibrillators and can administrate oxygen and monitor the heart. The wheels and suspension have also been improved to allow off-road routes to be taken if there is congestion on the journey to the hospital. The LifeBot 5 is one device that has taken mobile healthcare that step further. Developed by the US Army, its motto is 'saving lives in real-time' and the telemedicine system comes equipped with a live link to a doctor in the nearest hospital. This allows the hospital to make more accurate assessments of the patient's condition and to prepare the ward for any surgery that may be required.

Despite all the modern upgrades, reaching the hospital in the quickest time is still the key objective. Today's vehicles come complete with a device that can change red traffic lights to green at certain intersections and use the best GPS and mapping systems available. These aids will prevent the motorist from driving recklessly and reduces shake and vibration from the road. This will enable more intricate and efficient treatments to be undertaken during the way to the hospital.

The modern ambulance

The medicines and equipment that paramedics have at their disposal

Medical supplies
All modern ambulances must contain everything a patient could need on a journey, from medicine to defibrillators to breathing apparatus.

Communication
Ambulance staff communicate within the vehicle via hands-free audio links and panic buttons are fitted in case of emergency.

Lights
The bright flashing lights and piercing siren of an ambulance alert other drivers and pedestrians to its presence so they can quickly get out of the way

Interior
The surfaces inside an ambulance are easy to clean for greater control of infection and spillage.

Wireless medical equipment
Treatment carried out in the ambulance is recorded to help medics operate accurately while on the road to the hospital.

Stretcher
Stretchers are designed to comfortably transport the patient from the scene to hospital and can be wheeled or carried.

Computer system
A 'black box' is instal ed on modern ambulances to record the driver's speed, handling, signaling and overall driving safety.

Chassis
Modern chassis are constructed be both light and manoeuvrable by using a lining of felt to dampen vibrations.

Seating and safety belts
Paramedics now have specially designed seatbelts that allow them to treat the patient while safely restrained.

"The two turbochargers on board maximise acceleration and minimise turbo lag"

Future police cars

Meet the cars that will become part of an effective urban pursuit force

As well as looking sleek from the outside, the Interceptor is packed with state-of-the-art technology. The driver and passengers are protected by the sturdy Ford SPACE (Side Protection And Cabin Enhancement), which is both tough and comfortable. This system comes complete with a modern type of air bag that deploys between the passenger's head and the car window to give crucial protection in rollover collisions.

The Interceptor comes in two models: Sedan and Utility. Both are formidable adversaries to criminal activity with the Utility the slightly larger model that can carry more equipment and technology for longer, drawn-out pursuits. Both vehicles' drivetrain is ideally suited to 24-hour policing. The two turbochargers on board maximise acceleration and minimise turbo lag, meaning there is no hesitation when responding to an emergency call. This is part of a high-pressure direct-injection fuel system that makes the award-winning Ford 3.5-litre EcoBoost engine as efficient as possible while producing 365 horsepower (272 kilowatts).

All this power would be pointless if it wasn't for the all-wheel-drive system (AWD) that upholds the Interceptor's handling at high speeds and in tough corners. Most cars in today's market boast good power and handling, so what does the Interceptor have that civilian cars don't? The answer lies in the 220-amp alternator on board. Essentially a huge power pack within the vehicle, it helps power all the gizmos an officer will require in a day's policing, including radios, computers, video cameras and radar.

Inside the Interceptor

Discover the tech that makes the interceptor the way forward for police cars

Personal Safety System
Sensors operate the air bags so they can determine the size of a collision and distinguish between firefights and crashes.

Cooling system
An optimal amount of air flows through the car so it can cope with the heat generated during a typical day.

Structure and strength
Using safety-cell construction technology, the Interceptor has strategically placed crumple zones that absorb the energy of a crash.

Crash testing
The chassis of an Interceptor is so strong that it can pass a rear-end crash test at 120km/h (75mph) with flying colours.

Engine
Using Ford's own EcoBoost technology, the car's 3.5l V6 engine produces 365bhp (272kW) and has two turbochargers to prevent lag.

Wheels
An Interceptor is designed to maintain law and order 24 hours a day with its high strength five-spoke steel wheels.

The Ford Interceptor aims to meet the increasing demand for power and safety for law enforcement vehicles

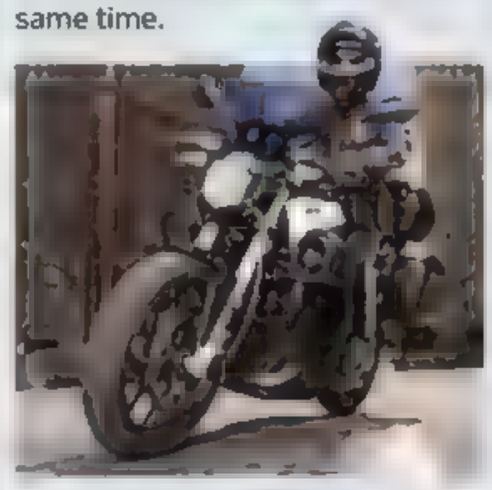
AMAZING VIDEO!

Take a look at Dubai's police supercar

Dubai's supercar cops

Green policing on two wheels

If an Interceptor isn't available, you can always hop on a motorcycle. As adept off road as it is on the streets, the Zero SP is quiet and exhaust free. Its electric powertrain gives it a top speed of 158 kilometres (98 miles) per hour and a range of 286 kilometres (178 miles) and it can recharge anywhere with a connection to the main grid. Its silence and lack of emissions mean the motorcycle can be used in tight situations such as compact city streets and dense pedestrian areas. Rather than go in all guns blazing, silent patrols offer an alternative solution to security and law enforcement. Its lightweight chassis and regenerative braking make it extremely manoeuvrable, allowing the bike to be inconspicuous and have the element of surprise when on the trail of a suspect. The Zero SP promotes a new way of policing that can undertake patrols effectively while being environmentally friendly at the same time.



The Zero SP is developed by Zero Motorcycles and promises an electric, exhaust-free way of policing

Doors
The ceramic ballistic front door panels help to protect the driver and front passenger by shielding them from bullets

Braking system
The heavy-duty braking system has specially designed callipers that create an effective cooling system on the wheels

"The Striker's powerful foam and water cannons make it an all-round firefighting machine"

Fire engines

The Oshkosh Striker

US company Oshkosh has packed all its technological expertise into this monster of a fire engine

The Oshkosh Striker is a rough, tough fire truck coming to an airport near you

Aviation fuel is extremely flammable so it is essential that a top-of-the-range fire engine is always on hand to fight the flames at airports across the globe. Enter the Oshkosh Striker. First produced in 2001, the vehicle had a revamp in 2010 and has now become the leading light in its class. Its combination of flame-smothering foam and quick acceleration make it a must at airports where smoke can choke a plane cabin in minutes. It has become so popular that it is used as the response vehicle of choice for US Air Force bases and even the White House.

The Striker's powerful foam and water cannons and a rapid response time make it an all-round firefighting machine. To achieve maximum acceleration, engineers removed unnecessary parts and replaced heavy materials with lighter ones. Small but vital additions such as all-wheel suspension, a high reach extendable turret and an intercooled engine make it a match for the strongest of infernos. Its simple control system and high-visibility windows make it easy to run and service so the vehicle is always available to fight fire.

There are three models of Striker: the 4x4, 6x6 and 8x8. Each one is larger and better equipped than the last, but all can be deployed to race down the runway in the face of an airport fire. With extra terminals springing up at airports worldwide and a constant stream of planes travelling through them, the Striker has never been in higher demand.

Cameras
To concentrate the water cannons on the epicentre of a fire, infrared cameras are used from the safety of the cabin.

Hull-piercing cannon
A fire breaking out inside an aircraft is no problem for the Striker, which can pierce up to 142cm (56in) of metal.

Cab
Five people can clamber in but the Striker is so simple to use that it can be operated by one person.

Foaming agent
The Striker comes equipped with 1,590l (420ga) of foaming agent and 11,356l (3,000ga) of water to extinguish the toughest infernos.

Firefighter protection
The crew are well protected by the glass windscreen that offers panoramic views of huge infernos.

Undertruck nozzles
Fuel spills are a common issue in airports so six undertruck nozzles have been attached to spray foam 360 degrees.

KEY DATES

A BRIEF HISTORY OF STRIKERS

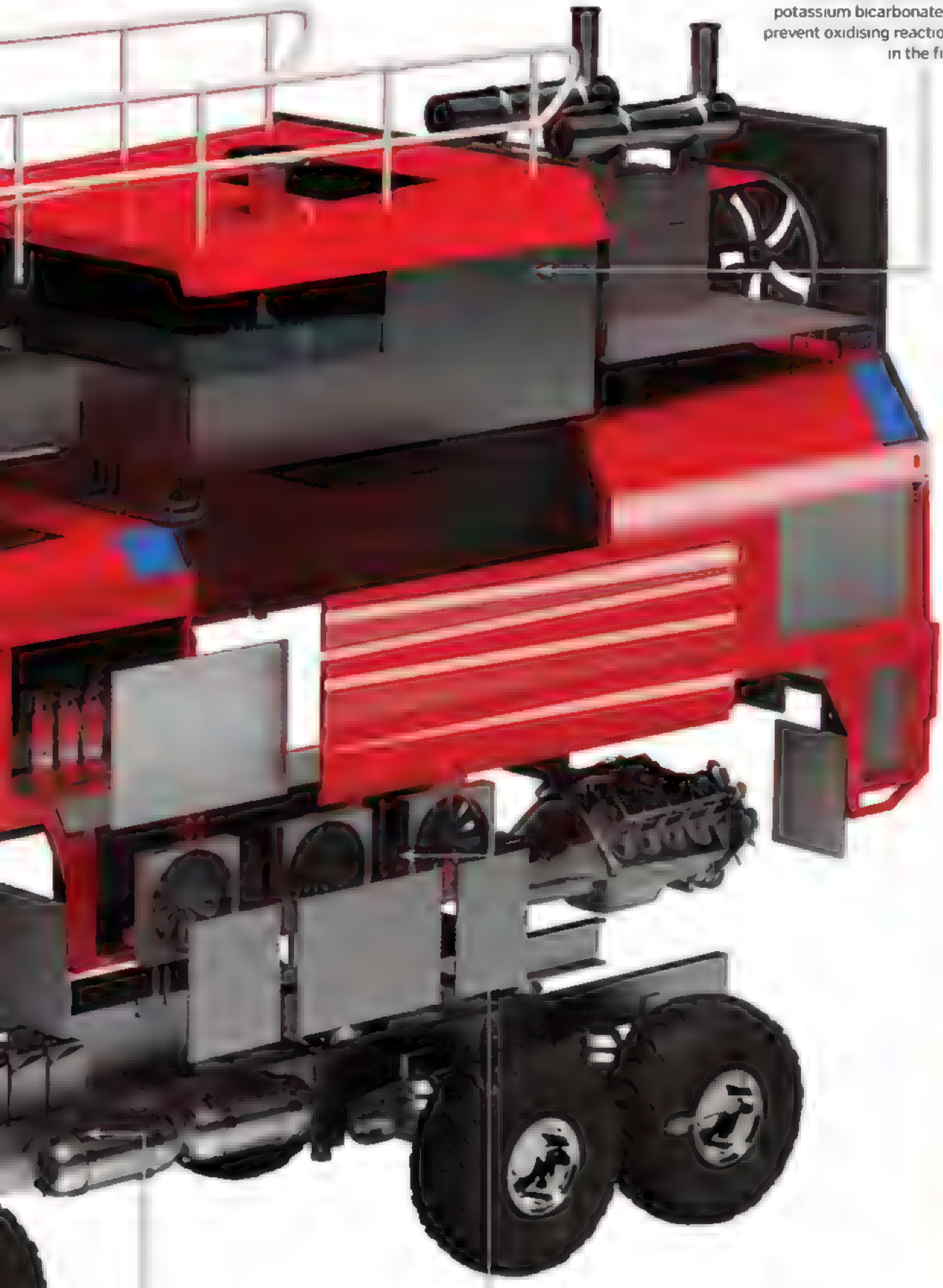
1968
Wisconsin corporation Oshkosh releases its first firefighting model, the MB-5. It is used in the US Navy and becomes a global leader.

Late-1960s
The MB-1 comes into production with a new 3,785l (1,000ga) water capacity that is double the MB-5.

1977
A 23,470l (6,200ga) P-15 becomes the second Oskosh vehicle to be used in the Air Force after the earlier P-4.

2001
The first Strikers are made, becoming the most revolutionary aircraft rescue and firefighting trucks.

2010
Strikers are given an upgrade, incorporating design ideas from firefighters to improve truck safety and performance.



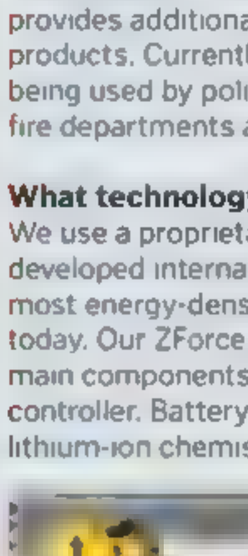
Chemical tank
As well as foam, the Striker holds high amounts of potassium bicarbonate to prevent oxidising reactions in the fire.

Lightweight chassis
It may weigh 44 tons, but the Oshkosh doesn't hang about, as it is constructed out of custom-designed light materials.

Engine
The V8 engine powers both the drivetrain and the cannons and uses computers to adjust the power to different situations.

Hop on the electric, exhaust-free police motorcycle

Interview with Scot Harden, VP of Global Marketing for Zero Motorcycles



What was the inspiration behind Zero?
Our mission is to transform two-wheeled recreation and transportation through our innovative, high-tech motorcycles. We aspire to provide all the attributes you normally expect from the motorcycling experience, the sense of adventure, thrill, freedom and personal fulfilment without any of the hassles associated with motorcycles. No heat, no vibration, no emissions and no sound.

How will police forces around the world utilise it in their fleets?
Over 50 agencies in the US are using Zero motorcycles as well as several high-profile international police/security organisations, including Hong Kong and Colombia. Our motorcycles are used for routine patrol, crowd control, event and private security efforts. The stealth nature of our products allows authorities to arrive on the scene of criminal activity unannounced and to patrol areas otherwise inaccessible. The low maintenance costs provides additional motivation to adopt our products. Currently Zero-fleet motorcycles are being used by police, military, university campus, fire departments and private security forces.

What technology is used in the Zero?
We use a proprietary drive train that has been developed internally by Zero and features the most energy-dense battery system available today. Our ZForce powertrain consists of three main components; the motor, battery and controller. Battery technology is based on lithium-ion chemistry

"Passengers of the future could be able to listen to their own music thanks to personal sound zones"

Creating a sonic boom

How the Super Hornet jet makes a really loud noise

One of the planet's most advanced fighter jets, the US Navy's F/A-18F Super Hornet is capable of staggering top speeds of up to 1,915 kilometres (1,190 miles) per hour – far beyond the speed of sound, which travels at a rate of 1,225 kilometres (761 miles) per hour. So what happens when aircraft such as the Super Hornet pass the magical 1,225-kilometre-per-hour mark, breaking the sound barrier?

As the aircraft travels through the air at a faster rate than the speed of sound, waves of pressure are created in front of and behind it. These waves can only travel at the speed of sound, which means as the aircraft accelerates past that threshold, they collide, creating one large shock wave. This large shock wave creates a loud noise similar to that of an explosion, which is known as the sonic boom. Many factors determine the intensity of a sonic boom including the aircraft's altitude, size and shape, as well as the weather conditions.

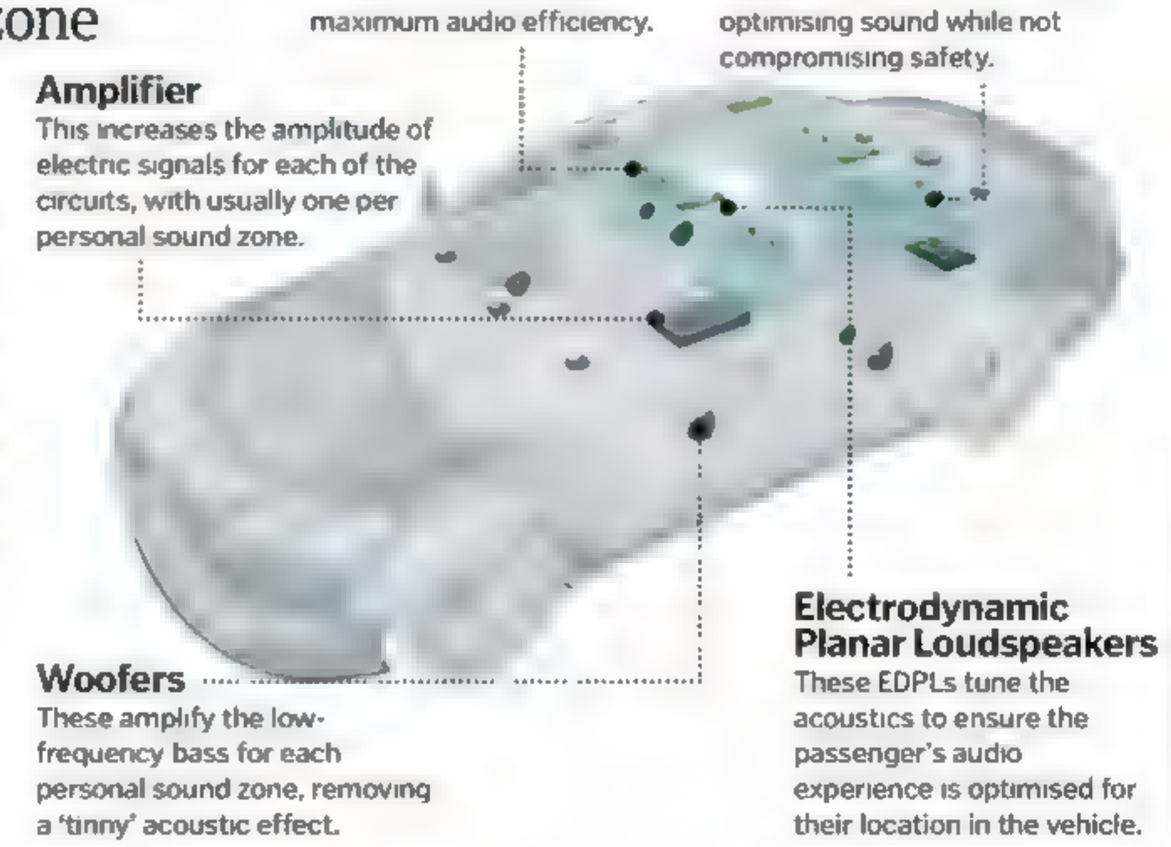
It takes just milliseconds for a jet fighter to create a sonic boom

Cutting-edge car audio

Listen to music in your own personal sound zone

Ever had to endure a car journey with nothing but the tedious resonance of your parents' favourite music for company? Thanks to cutting-edge technology currently being piloted in the automotive industry, passengers of the future could be able to listen to their own music thanks to personal sound zones. The technology works by placing more small yet powerful micro-speakers in the headrest of a seat, so the sound is nearer to the head of each individual passenger – but there's more. A filter matrix then modifies the wave field of the standard car audio speakers and headrest speakers to the desired frequency of the occupant, providing cross-talk cancellation (CTC) against other sounds.

Aside from being able to listen to your own music, this breakthrough in audio technology presents a host of benefits to occupants of a vehicle. For example, with the sound zones, any navigation prompts to the driver will have little impact on the audio experience of others, and incoming calls can effectively be 'passed' through the car to the intended recipient.



THE STATS

100% ELECTRIC ENGINE

3.5 hours CHARGE TIME

MOTOR 5bhp or 17bhp

BATTERY 6.1kW

TOP SPEED **80km/h (50mph)**

The world's first 3D-printed car

Local Motors' new electric car could soon be printed near you in just 24 hours

Being able to buy your own 3D-printed car from a factory nearby may soon become a reality with the Strati from Local Motors. Created using BAAM (big-area additive manufacturing), the world's first fully drivable 3D-printed car will be electric and have just 40 parts – significantly fewer than the 2,000 parts most vehicles include. Mechanical components such as the battery, motors, wiring and suspension are sourced from Renault's Twizy, an electric city car, while everything else on the Strati that could be integrated into a single material piece – including the frame, exterior body and some interior features – has been printed using ABS plastic reinforced with carbon fibre.

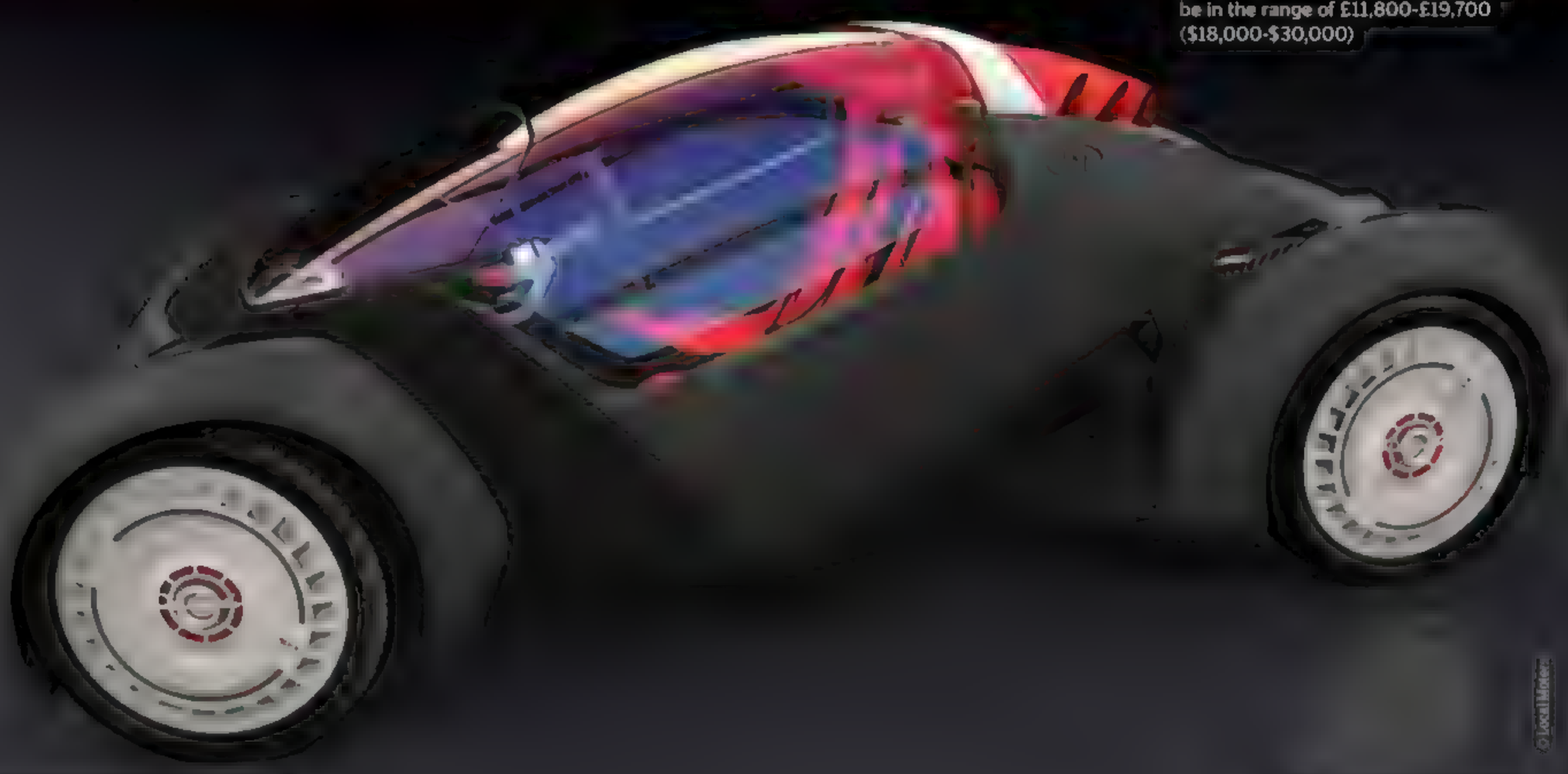
The two-seater design currently takes 44 hours to print, and Local Motors aims to be able to speed the process up to 24 hours without any reduction in build quality. The Strati's body is made up of approximately 212 layers laid down slice by slice; making the Italian word for layers, 'strati', an ideal name. Driving the car is an electric motor powered by a 6.1-kilowatt battery that can be recharged in a comparatively fast three-and-a-half hours and propel the Strati up to a top speed of about 80 kilometres (50 miles) per hour.

Local Motors is developing the car as an open-source project, allowing all digital 3D-print files and build manuals to be freely downloaded and even modified by individual users. With the company also intending to open 100 microfactories near major cities worldwide within the next ten years, the automotive industry certainly seems set for a 3D-printing revolution!

What is big-area additive manufacturing?

Similar to the process used by at-home desktop 3D printers, BAAM relies on a digital 3D model part becoming sliced into layers, which are then used to generate the real layers of ABS plastic that are created by the 3D printer when laying down the material slice by slice. Aside from the print size required, one of the major differences between a desktop 3D printer and the system used to create the Strati is the feed system. The Local Motors team use a pellet feed as opposed to filament-fed extruders as feedstock is significantly cheaper than filament, making it easier to experiment with more material combinations. This is a huge help with elements such as the durable carbon-fibre composite ABS used to print the Strati's components.

Carbon-fibre composite ABS may be difficult to find in filament form, but there are many new metallic filaments you can buy for use with a 3D printer



The 3D-printed Strati will reportedly go on sale in 2016, with cost likely to be in the range of £11,800-£19,700 ($18,000-$30,000)

© Local Motors

15 FACTS YOU NEVER KNEW ABOUT ECLIPSES

Eclipses are one of nature's most amazing spectacles, a result of our Moon's orbit around our planet

the grey dark of a rainy day, but dark like the night. The only time you will ever see this is during a total solar eclipse, which is one of nature's most breathtaking eclipses. It happens when the Moon moves in front of the Sun for a few minutes, blocking its light and underneath the Moon's shadow darkness falls.

Total solar eclipses are rare and in a way it is an incredible stroke of luck that we have them. The Sun's distance from Earth just happens to be about 400 times the Moon's distance from our planet. The Sun also happens to be about 400 times larger than the Moon, so thanks to

size in the sky, meaning that during an eclipse the Moon can fit precisely over the Sun. We have to say 'about' a lot because Earth's orbit and the Moon's orbit are not circular but elliptical, meaning sometimes they can be a bit further away, or a bit nearer. This results in the Sun sometimes appearing larger than the Moon during some eclipses, leaving a ring of light from the Sun around the Moon's silhouette. We call this an annular eclipse.

An eclipse begins at 'first contact' when the Moon's disc first touches the Sun's disc. You won't notice a change in the light at this point – in fact it won't get dark until the Moon has

disc touches the Sun's apparent dis
– which is how we describe the Sun being blocked by the Moon – can last for several minutes. 'Third contact' happens when totality ends and the Moon begins to move away from the Sun and daylight returns once more. 'Fourth contact' is when the Moon moves completely off the Sun and the eclipse ends.

The Moon is very slowly moving away from Earth at a rate of 3.8 centimetres (1.5 inches) per year, so eventually it will appear too small to completely cover the Sun. Luckily, this day won't arrive for at least another 500 million years!

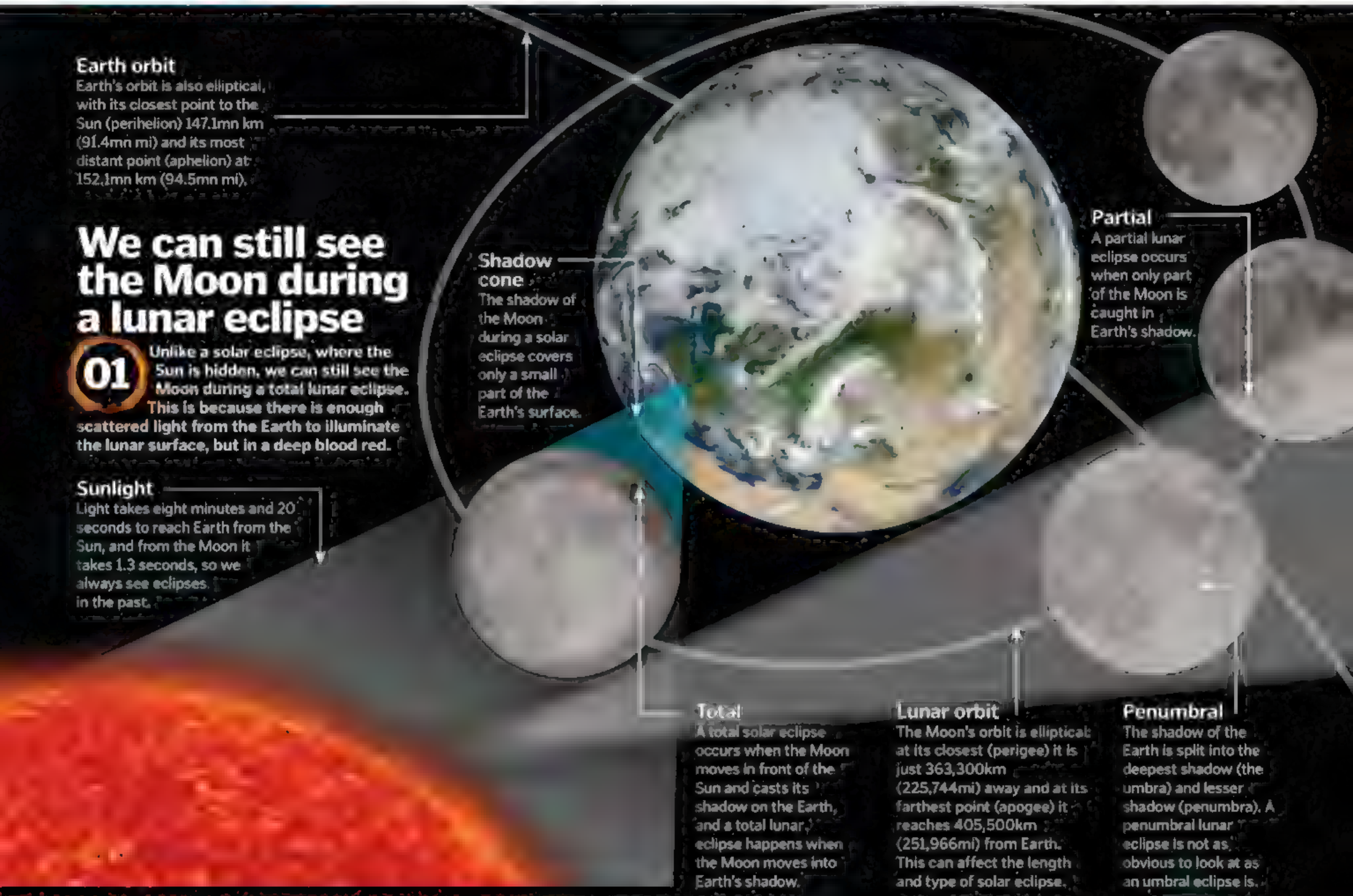
RECORD BREAKERS
LONGEST ECLIPSE

74minutes

LONGEST ECLIPSE OBSERVATION

If you can move fast enough, you can keep up with the supersonic shadow of the Moon during an eclipse. In 1973, astronomers flew on a Concorde, moving at Mach 2, to stay in the path of totality for 74 minutes.

DID YOU KNOW?

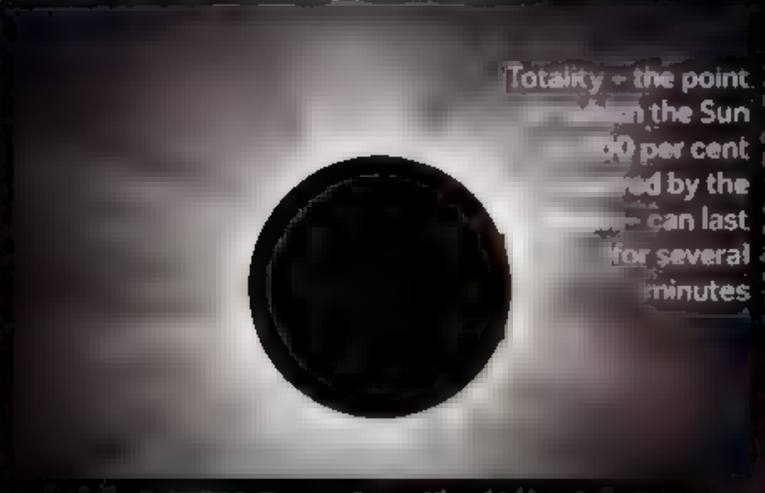


We can still see the Moon during a lunar eclipse

01 Unlike a solar eclipse, where the Sun is hidden, we can still see the Moon during a total lunar eclipse. This is because there is enough scattered light from the Earth to illuminate the lunar surface, but in a deep blood red.

The length of totality can vary

02 Some eclipses are very short, with totality lasting just a couple of minutes. Others can last six or seven minutes. The reason for the difference is a result of the elliptical orbits of Earth and the Moon. When the Moon is closer to Earth in its orbit, it moves faster. The same for the Earth around the Sun, and this all affects the speed at which we see the Moon move across the Sun during a solar eclipse.



You can see the Sun's atmosphere

03 The Sun has an atmosphere, split into two parts. The lower part is called the chromosphere where the temperature rises from 6,000 to 20,000 degrees Celsius (10,832 to 36,032 degrees Fahrenheit). The upper part is called the corona and can reach temperatures in excess of 1 million degrees Celsius (1.8 million degrees Fahrenheit). During totality you can see this corona as flares of light around the hidden Sun. You might also catch a glimpse of the chromosphere as a red tinge at the edge of the Moon at third contact.

You can see the planets during an eclipse

04 If you are lucky enough to see a total solar eclipse, take a few moments to also glance around the sky. In the darkness the stars and planets will pop out. Closest to the Sun will be Venus and Mercury, but you could also see other planets, depending where in the sky they are at the time.

During a total eclipse, you should be able to see the stars and naked eye planets – depending on the time of year – as the sky turns dark.

"We can see eclipses taking place on Jupiter with our back-garden telescopes"

UK solar eclipses are rare

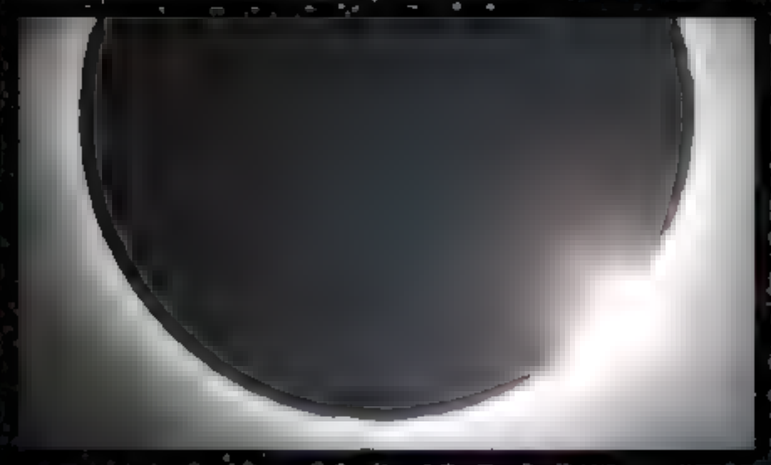
05 Total solar eclipses seen from the UK are very rare. The last one was in 1999 and the next won't be until 23 September 2090, where Cornwall will be in the umbral shadow for two minutes and ten seconds. However, there will be partial solar eclipses visible in 2018 (only Shetland, Orkney and the northern coast of Scotland), 2021, 2022 and 2026.

Solar eclipse hunters will need a passport

06 There are plenty of opportunities to view a solar eclipse over the next ten years if you are willing to travel. Following the eclipse this March, there are total solar eclipses on 9 March 2016 (Indonesia, the Pacific), 21 August 2017 (USA), 2 July 2019 (Argentina and Chile) and the same again on 14 December 2020, 4 December 2021 (Antarctica), 20 April 2023 (Indonesia and Australia) and 8 April 2024 (Mexico, USA, Canada). There are also annular eclipses in 2016, 2017, 2019, 2020, 2021, 2023 and 2024.

They can create diamond rings

07 Just at the moment totality begins or ends, a spectacular effect takes place that is called the 'diamond ring' – a bright burst of light appears, looking very much like the jewel in a diamond ring. This is caused by sunlight bursting through gaps between mountains on the edge of the Moon.

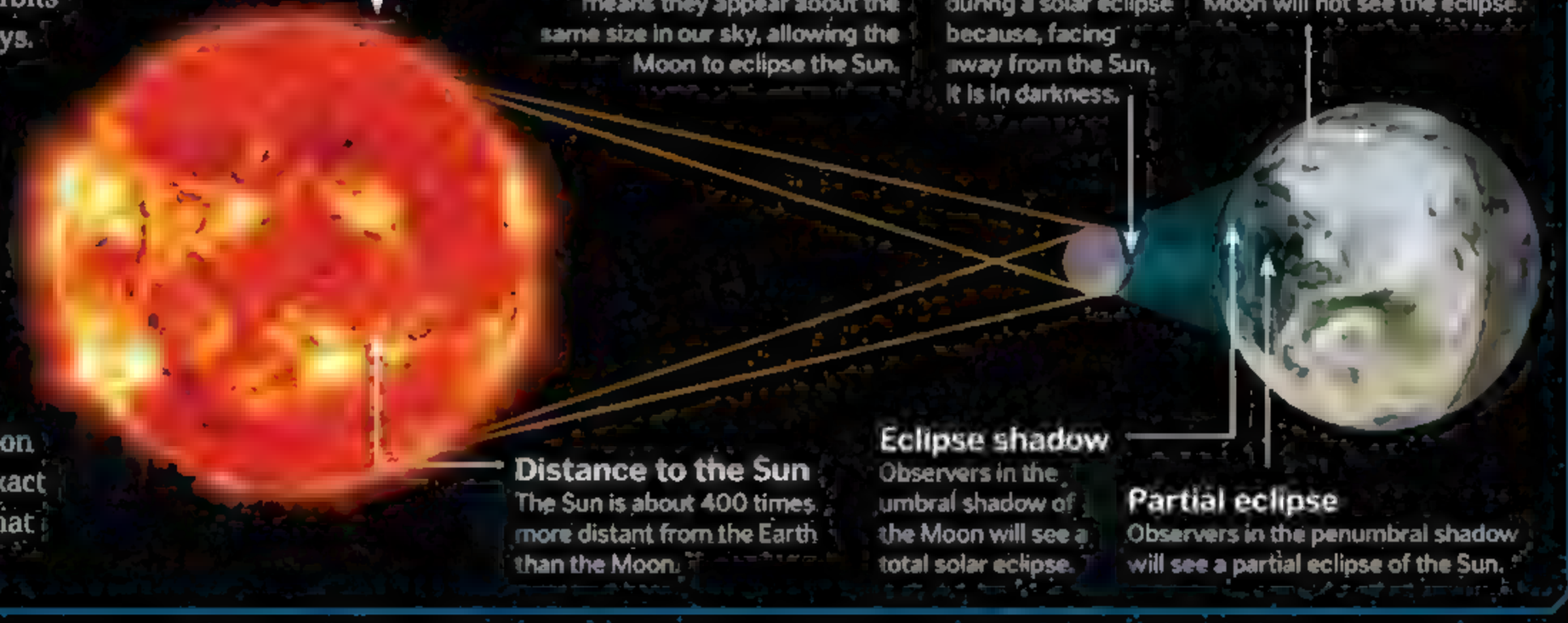


Sunlight bursting through gaps between mountains on the Moon creates a 'diamond ring'

How a solar eclipse forms

A solar eclipse is a consequence of an alignment of the Earth, Moon and Sun

Eclipses are all a result of orbits. The Moon orbits the Earth once every 27.3 days. The Earth orbits the Sun once every 365.2 days. Their orbits are elliptical, meaning their distance from their parent body can change throughout an orbit. The tilt of the Moon's orbit relative to the ecliptic (the path of the Sun through the sky) is 5.1 degrees. A solar eclipse happens only when the Moon crosses the ecliptic at the exact position that the Sun is at that moment in time.



Solar and lunar eclipses come in pairs

08 There is always a lunar eclipse either two weeks before or two weeks after a solar eclipse. This is because the alignment between the Sun, Moon and Earth is still close enough that, a fortnight before or after a solar eclipse, when the Moon is on the other side of the Earth, the Moon can fall into Earth's shadow.

The characteristic reddish hue of a lunar eclipse will often appear not long before or after a solar eclipse

How did Columbus make use of the 1504 lunar eclipse?

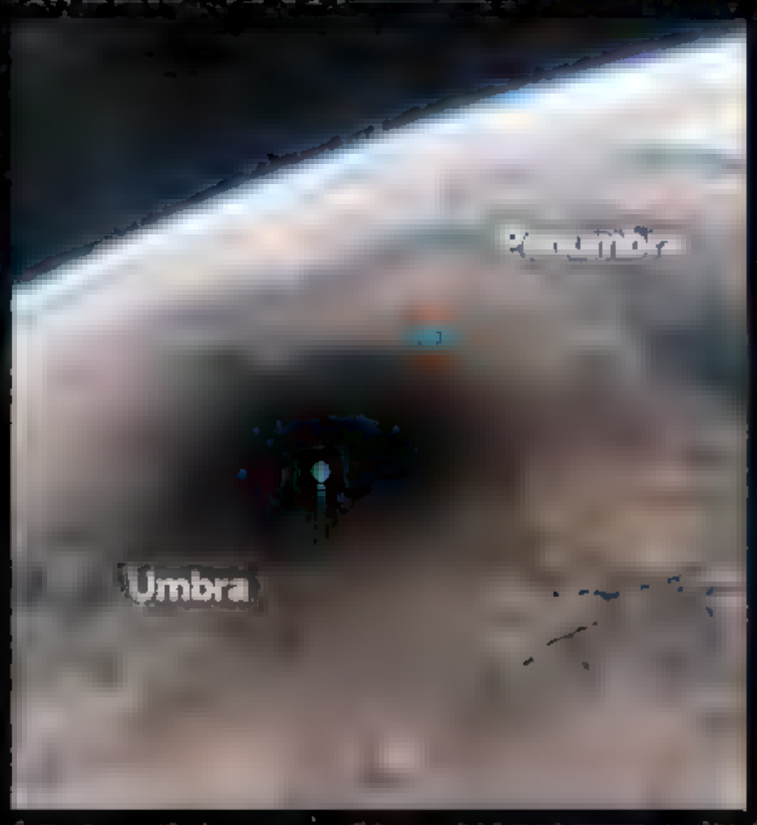
A As distraction to escape from the natives B 'Predicting' it to get food C Practice his astronomy in the darkness

Answer:
After explorer Christopher Columbus became stranded in the Caribbean, he and his crew became dependent on food from the local tribes. He 'predicted' the lunar eclipse since he knew it would secure the respect of the superstitious natives.

DID YOU KNOW?

The Moon's shadow moves very fast

09 The Moon's shadow moves quickly across the face of the Earth, from west to east, faster than the speed of sound – the eclipse shadow at the equator travels at 1,730 kilometres (1,075 miles) per hour. This is because the Moon is orbiting Earth at 3,400 kilometres (2,113 miles) per hour, counterbalanced by the Earth's rotation at 1,670 kilometres (1,038 miles) per hour. This is also why the Moon moves across the sky faster than the Sun.



There is more than one type of shadow

10 A shadow is divided into two parts – the umbra and the penumbra. The umbra is the central, deepest part of the shadow. The penumbra is where only part of the source of light is blocked. Total eclipses are seen in the umbra, while partial eclipses are seen in the penumbra.

They require syzygy

11 Eclipses occur during a particular alignment of the Sun, Moon and Earth called syzygy, which is when all three bodies are arranged in a straight line.

Ancient eclipses

12 In the past, total solar eclipses have often deemed to be bad omens or portents of doom, or the anger of the gods, prompting both wars and peace to begin. However, as far back as the ancient Babylonians and Chinese in the 25th century BCE, astronomers have been able to predict the motion of the Moon and the Sun and when eclipses would occur.

You can see a lunar eclipse this year

13 Lunar eclipses are much more common than solar eclipses, occurring twice a year in different parts of the world. The next total lunar eclipse visible from the UK will be on 28 September 2015, followed by another on 21 January 2019, with several partial eclipses between those two dates.

Eclipses are relatively rare

14 On average, total solar eclipses happen every 18 months, although sometimes it can be several years between eclipses. They don't occur every month because the Moon's orbit is tilted with respect to the Earth's orbit around the Sun, so it is only rarely that the Moon's path across the sky intersects with the Sun's.

They must be observed with care

15 It is very dangerous to look direct at the Sun without using special eclipse glasses or a telescope with a specialist solar filter. This is because the Sun is so bright it can damage your eyesight, or even permanently blind you. Even if 99 per cent of the Sun's surface is blocked by the Moon, the remaining per cent is still intense enough to burn your retina. So here are some safe options for observing eclipses, or the Sun in general.

If using eclipse glasses, check they do not have any damage. Even a pinhole could damage your eyesight.

Try projecting the image of the Sun through a telescope and onto a piece of white card. Keep the finderscope covered, in case small children accidentally look through it. Gaps between leaves in trees can also act as natural pinholes to project the Sun's image.

You can also use specialist solar filters and telescopes. Produced by companies such as Coronado and Lunt, these can be a bit expensive but they allow you to view the Sun at other wavelengths of light, such as hydrogen-alpha, which appears orange, blocking out the dangerous light.

Eclipses on other planets

Solar eclipses do occur on other planets and moons in our Solar System, but because they do not have the size ratio that we have between the Earth and our Moon, their eclipses are not as spectacular. Mercury and Venus cannot have eclipses because they do not have any moons. Mars's two moons are too small to totally obscure the Sun, but the rovers on the Red Planet have photographed Phobos (the larger of the pair) moving in front of the Sun in a kind of partial eclipse. We can see eclipses taking place on Jupiter with our back-garden telescopes, in the form of the shadows of its four major moons cast on the uppermost cloud layer of the giant planet. Astronomers call these 'shadow transits' and several can happen at once. We can also see Jupiter's moons go into eclipse in the shadow of Jupiter. Similar eclipses can take place on all of the giant planets of the outer Solar System, and even on the dwarf planet Pluto where its largest moon Charon can eclipse the distant Sun a couple of times each century.

The shadow of the Jovian moon Ganymede can be seen transiting across the surface of gas giant Jupiter

"Google Sky is an interactive atlas of the universe, mixing images from some of the largest observatories"

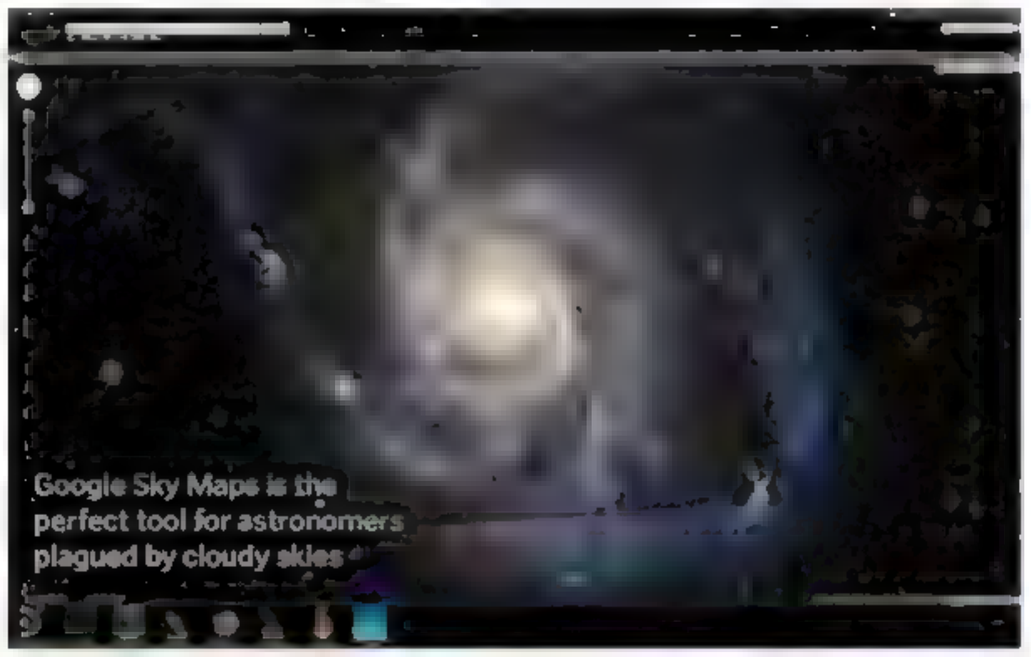
Google's guide to the night sky

Explore the universe from the comfort of your own desktop or smartphone

The night sky is a place of mystery, but thanks to the Google Sky Maps app you can demystify the stars, planets and galaxies above your ahead. By utilising the Global Positioning System (GPS) of satellites that can tell your smartphone its location, you can point your smartphone in any direction in the sky and Google Sky will tell you what it's pointed at. It could be the Orion nebula, the planet Mars, the constellation of Leo, or something completely different.

GPS works thanks to a network of satellites above our heads that are able to calculate your location by sending out continuous radio signals. Every place on Earth is in view of at least four of these satellites, and the GPS receiver in your phone picks up these signals and triangulates its location based on how long it takes the radio signal to arrive from each satellite. The app is then able to work out what view of the stars you should have from your location.

You can switch off the GPS function and explore the universe by scrolling around, just as you would on Google Maps. You can search its database to find practically any deep-sky object, or apply layers that depict the universe in different wavelengths of light, from infrared to ultraviolet. The Sloan Survey supplies many of the background images of the sky. It is conducted by a 2.5-metre (8.2-foot) aperture telescope in New Mexico, USA. It has been mapping the sky since 2000, imaging galaxies, finding new asteroids and supernovae, and cataloguing 500 million objects in the universe.



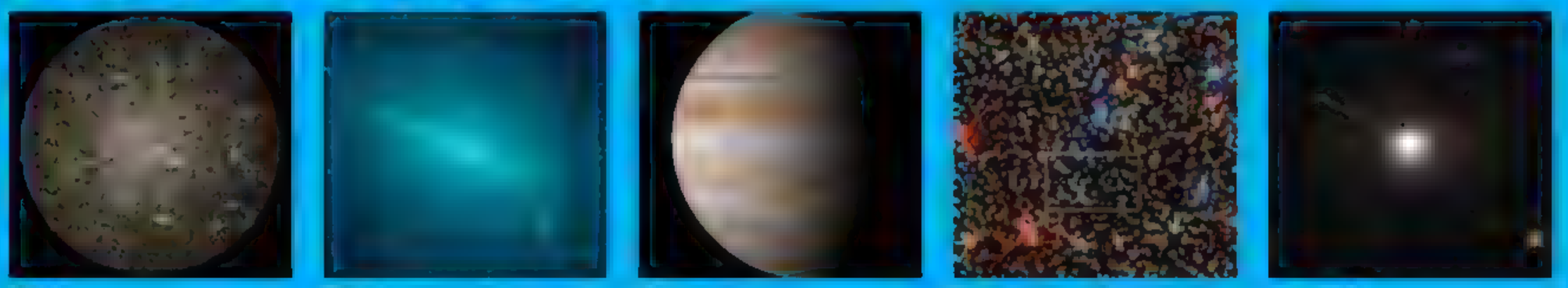
Google Sky Maps is the perfect tool for astronomers plagued by cloudy skies

Sky Surveys

A large chunk of the fantastic imagery in Google Sky comes from two surveys of the night sky – the Sloan Digital Sky Survey and the Digitized Sky Survey. The Sloan Survey is conducted by a 2.5-metre (8.2-foot) aperture telescope at the Apache Point Observatory in New Mexico, USA, which has five filters that work at different optical wavelengths: 355.1nm (ultraviolet light), 468.6nm (blue light), 616.6nm (orange), 748.0nm and 893.2nm (both near-infrared). It has been mapping the sky since 2000, imaging fainter and fainter galaxies, finding new asteroids and supernovae, and cataloguing a whopping 500 million objects in the universe.

The Digitized Sky Survey uses old observations, from a time before computers and CCD cameras, when images of the sky were taken on photographic plates. The Digitized Sky Survey aims to scan all these archive images to create a new digital atlas, and is being carried out by a variety of institutions, observatories and universities led by the Space Telescope Science Institute in Baltimore, USA.

5 sights to see in the sky



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"The colour of each planet is determined by what they are made up of"

The colours of the planets

Discover the science behind the colours in our Solar System

Of the eight planets in our Solar System, only two can't be seen unaided from Earth – Uranus and Neptune. And even then, unless you're observing through a telescope, the physical appearance of almost all planets will be difficult to perceive. Except of course Earth's neighbouring planet, Mars, which even ancient cultures correctly documented as being red, as its orange-red glow is distinguishable from Earth.

Space missions and scientific advancements in the last century have greatly improved our perception of the planets, including those closest and farthest away from the Sun. As a result we are now finally able to identify a planet's true colour and – more importantly – understand why it appears as such.

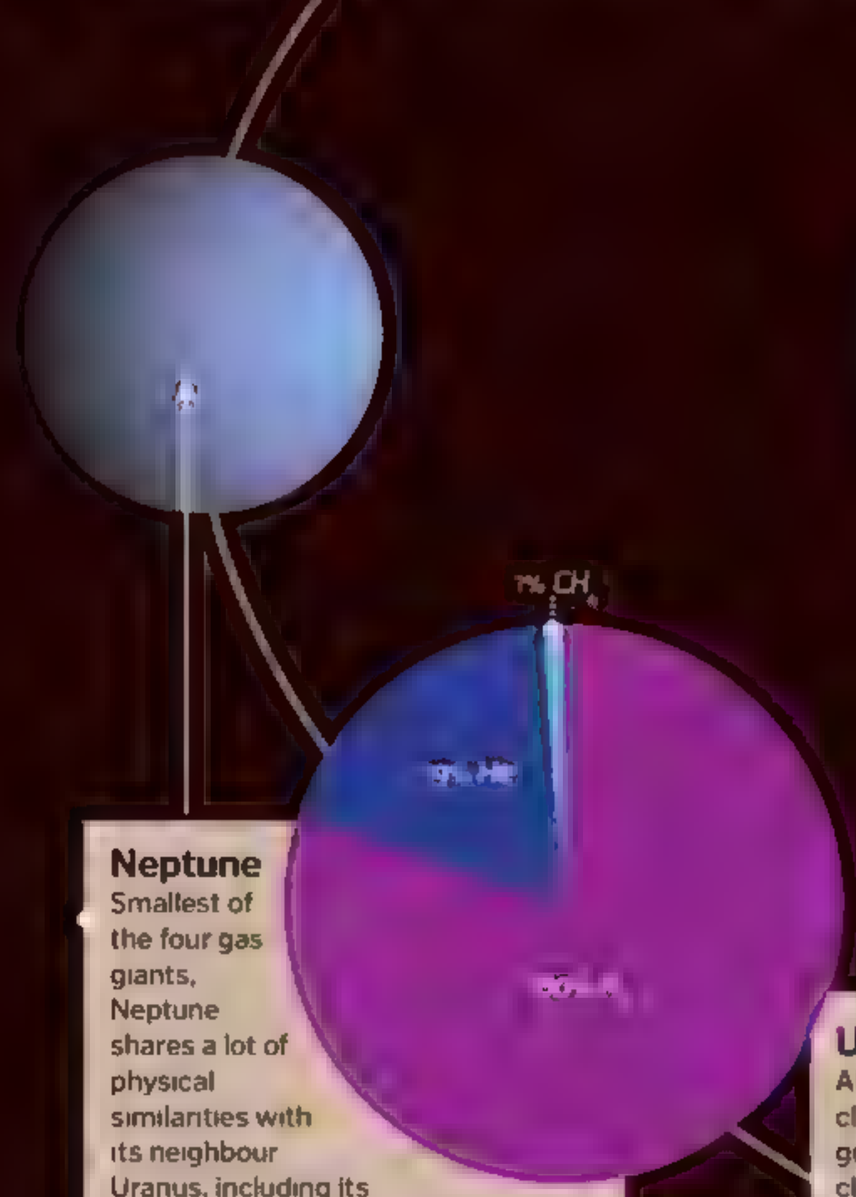
The colour of each planet is determined by what they made up of, and in some instances, how their atmospheres absorb and reflect light from the Sun.

The four terrestrial planets, which have solid rock surfaces, are mostly grey or reddish-brown in appearance due to elements such as iron found on the surface. However, the surface of Venus is difficult to detect from space, as a dense atmosphere and thick clouds of acid surround it. The sulphur present in the clouds reflects the light and gives Venus its noticeable yellow colouring. A similar principle applies when it comes to determining the colours of the four gas giants. Uranus and Neptune, for example, appear to us as blue because methane gas present in their atmospheres absorbs red light, enabling them to only reflect blue.

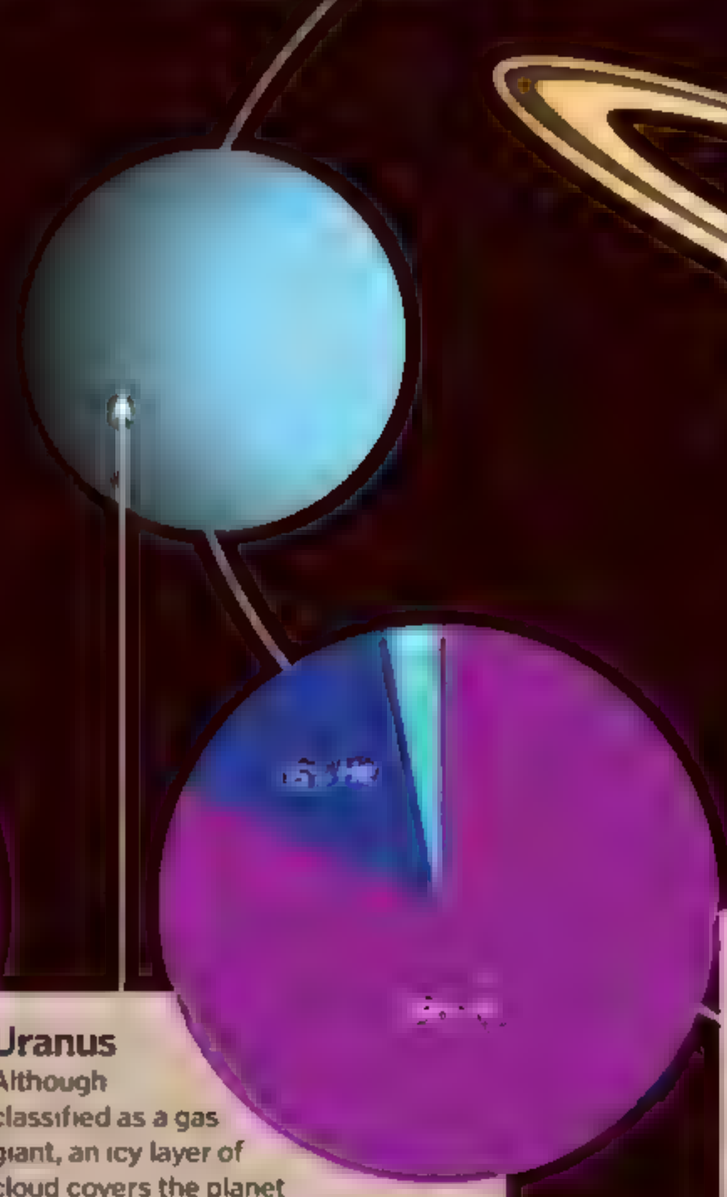
Planetary colour palette

Here's how each planet is coloured, with each colour indicative of a certain element

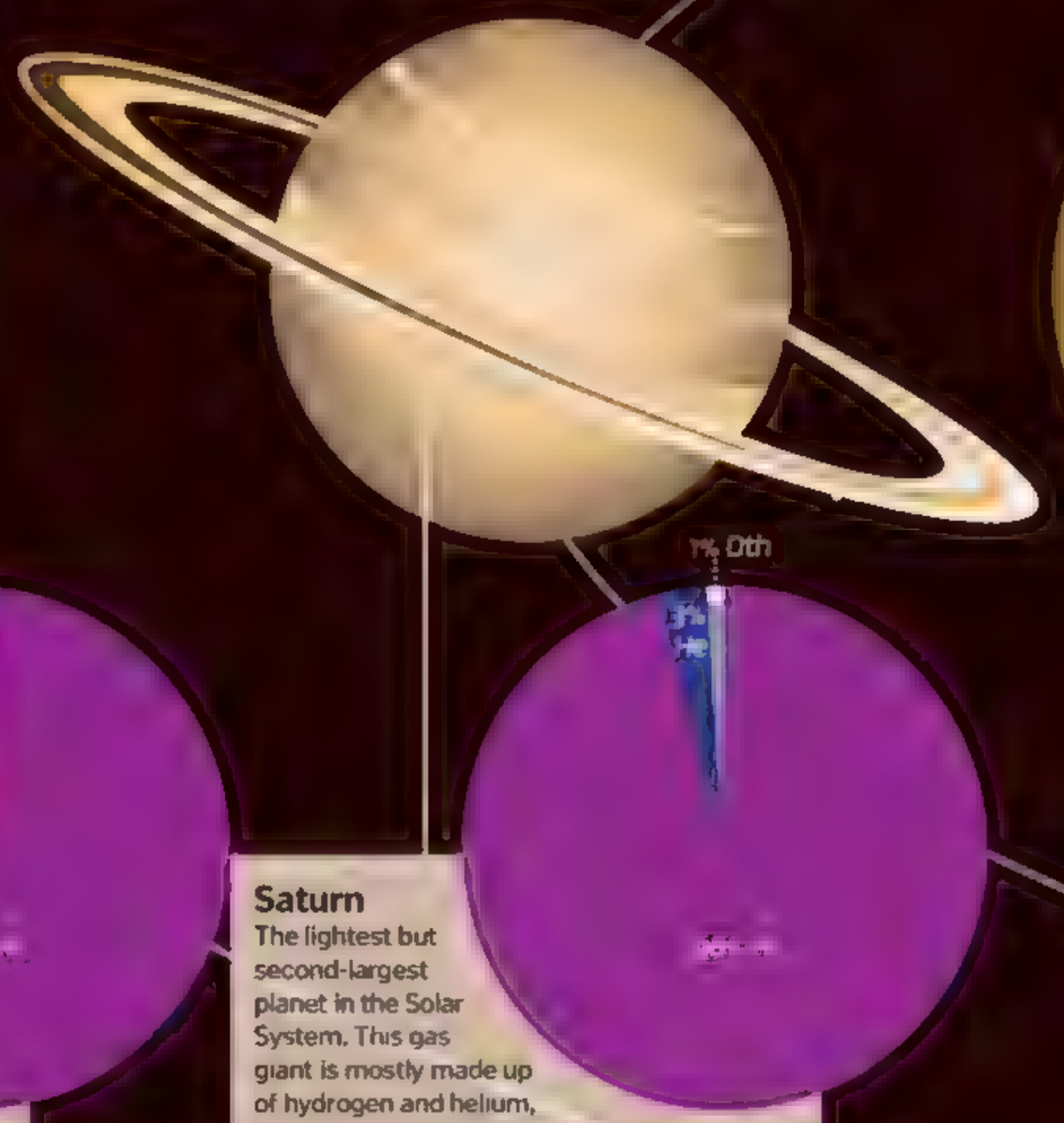
- Hydrogen (H_2)
- Carbon dioxide (CO_2)
- Helium (He)
- Nitrogen (N_2)
- Oxygen (O_2)
- Methane (CH_4)
- Sodium (Na)
- Argon (Ar)
- Other gases (Oth)



Neptune
Smallest of the four gas giants, Neptune shares a lot of physical similarities with its neighbour Uranus, including its blue colouring. It's considered the windiest planet, with speeds recorded at around 2,414km/h (1,500mph). Extreme storms are also known to occur in its atmosphere and the planet also features a giant storm spot like Jupiter.



Uranus
Although classified as a gas giant, an icy layer of cloud covers the planet Uranus. The coldest planet in our Solar System, temperatures at cloud level drop to below -220°C (-364°F). Methane in its atmosphere gives Uranus its distinct turquoise appearance; as red light is absorbed, only green-blue light is reflected.



Saturn
The lightest but second-largest planet in the Solar System. This gas giant is mostly made up of hydrogen and helium, but traces of ammonia, phosphine, water vapour and hydrocarbons in its atmosphere give the planet its distinct yellowish-brown colour. Saturn's famous rings, which are primarily made up of water ice, share a similar hue, but also vary in colour depending on density and the presence of other materials.

5 TOP FACTS
PLANETARY EXTREMES

Planets with moons
1 Earth is not the only planet in our Solar System to have a moon. Mars has two small moons, while the gas giants have many. Jupiter has at least 67

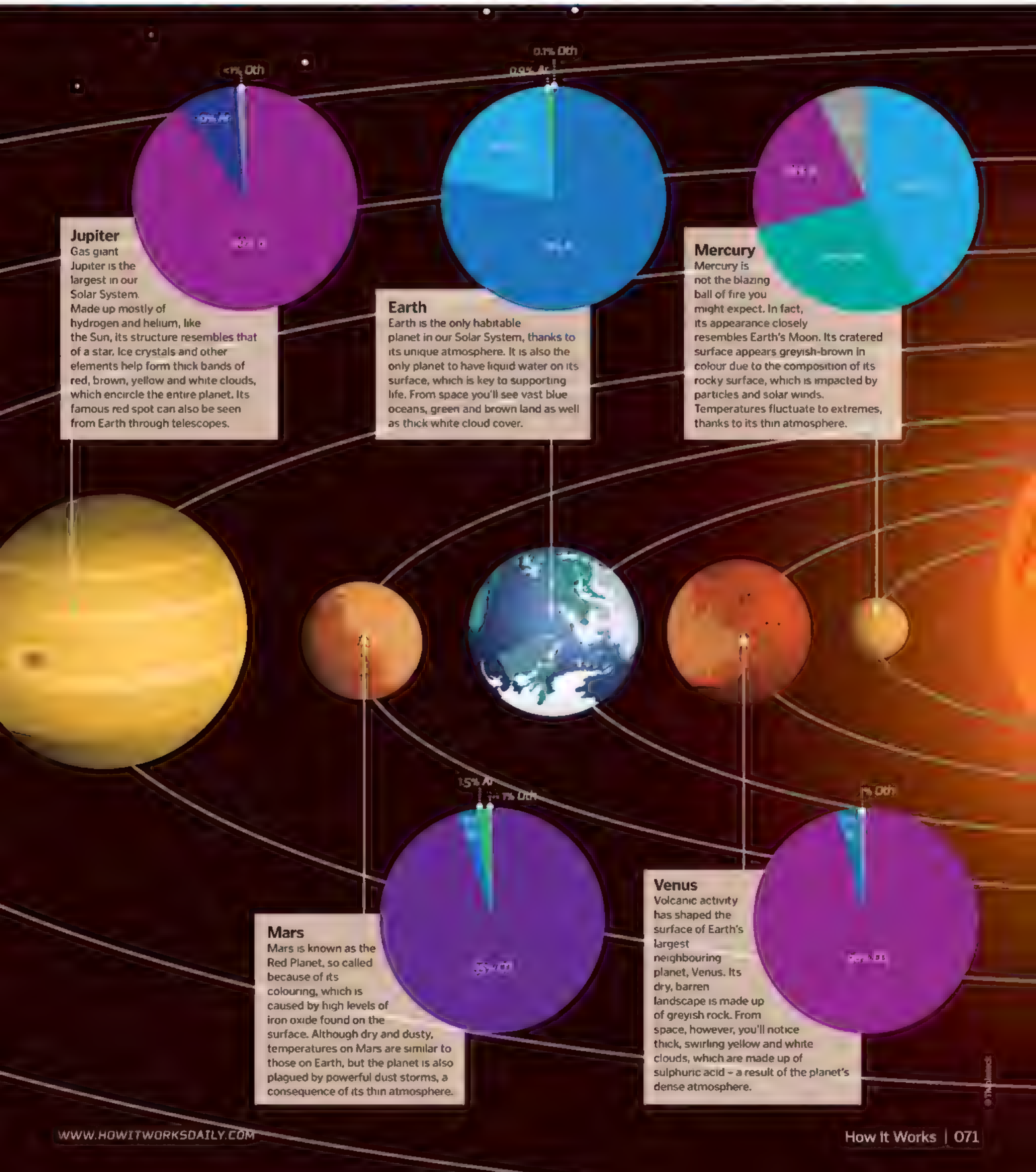
Hottest planet
2 Temperatures on Venus can reach 470°C (878°F). The planet's dense atmosphere traps heat from the Sun, making it the hottest planet in our Solar System.

Tallest mountain
3 Mars is home to the largest volcano in the Solar System, Olympus Mons. At a height of 25km (15.5mi), it's about three times the height of Mount Everest on Earth.

Largest storm
4 Scientist Robert Hooke first documented Jupiter's Great Red Spot in 1664. It's so large that Earth could actually fit inside it with room to spare.

Longest year
5 Neptune is the farthest planet from the Sun, around 4.5bn km (2.8bn mi) away. Because of this, it takes Neptune over 60,000 days to complete a full orbit.

DID YOU KNOW?



"Being so tough makes the tardigrade the perfect astronaut"

Water bears in space

Take a look at the first animal to survive in outer space

The tardigrade is sturdy enough to handle anything. These small yet robust animals, just half a millimetre (0.02 inches) long, can be found anywhere from the beyond-freezing conditions of the South Pole to the high pressures of the ocean floor. What's more, they can survive more than ten years without food or water, in conditions just above absolute zero to over 150 degrees Celsius (302 degrees Fahrenheit). Scientists call such hardy creatures extremophiles.

Being so tough makes the tardigrade the perfect astronaut and, in 2007, a group of these so-called 'water bears' made the journey into space aboard the European Space Agency's Foton-M3 mission. True to form, these resilient creatures withstood the harsh combination of extremely low pressure, cold temperatures and intense radiation – capable of damaging DNA – with only slight signs of wear and tear when they returned to Earth ten days later. The tardigrade became the first animal to survive exposure to space. Another group of tardigrade astronauts then headed into space onboard NASA's Space Shuttle Endeavour to visit the International Space Station as part of Project BIOKIS, which among other things sought to learn more about how these creatures can naturally defend themselves from the extreme stresses caused by the conditions in space.

Tardigrades, also known as 'water bears', are extremely hardy animals.

© Eye Of Science / Science Photo Library

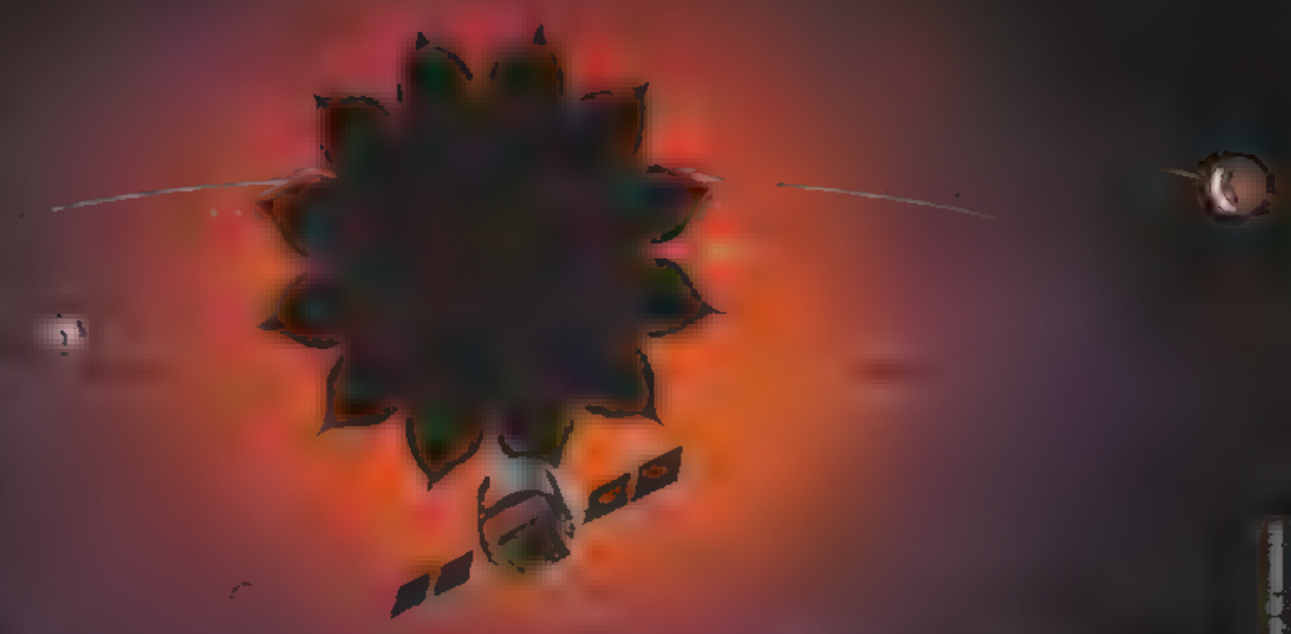
Hunting for alien planets

By blocking out light using a 'space parasol' we might be able to find alien worlds

Astronomers have a problem when it comes to trying to take images of planets around other stars. Just think of how much glare comes from our Sun – the stars are no different. To be able to see planets that are very close to their stars, astronomers need a way of blocking the glare of a star's light so that we can see the planets in close attendance.

The tool for this job is called a starshade. It is new technology, but could be flown on a planet-finding space mission in the not-too-distant future. The idea is to have a kind of shade, shaped something like a sunflower, measuring 34 metres (112 feet) across and floating in space in formation tens of thousands of kilometres ahead of a space telescope. The petal shape means the edge of the shade is not sharp, which means the rays of starlight do not bend as much, so the shadow cast by the shade is darker.

Scientists are conducting tests in the desert, using bright LED lights and prototype shades. If successful, starshades could soon be employed on missions such as the James Webb Space Telescope, which is due to launch in 2018.



An artist's impression of a starshade, blocking the glaring light of a star so its orbiting planets can be seen.

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Roman sieges

How the Romans overcame even the thickest walls to build an empire

Through centuries of campaigns, the Roman military drove the expansion of their Republic and later their Empire, dominating vast swathes of Europe, North Africa and the Middle East. They forged their formidable reputation thanks to a well-trained army and cutting-edge technology, as well as their ingenious tactics and engineering.

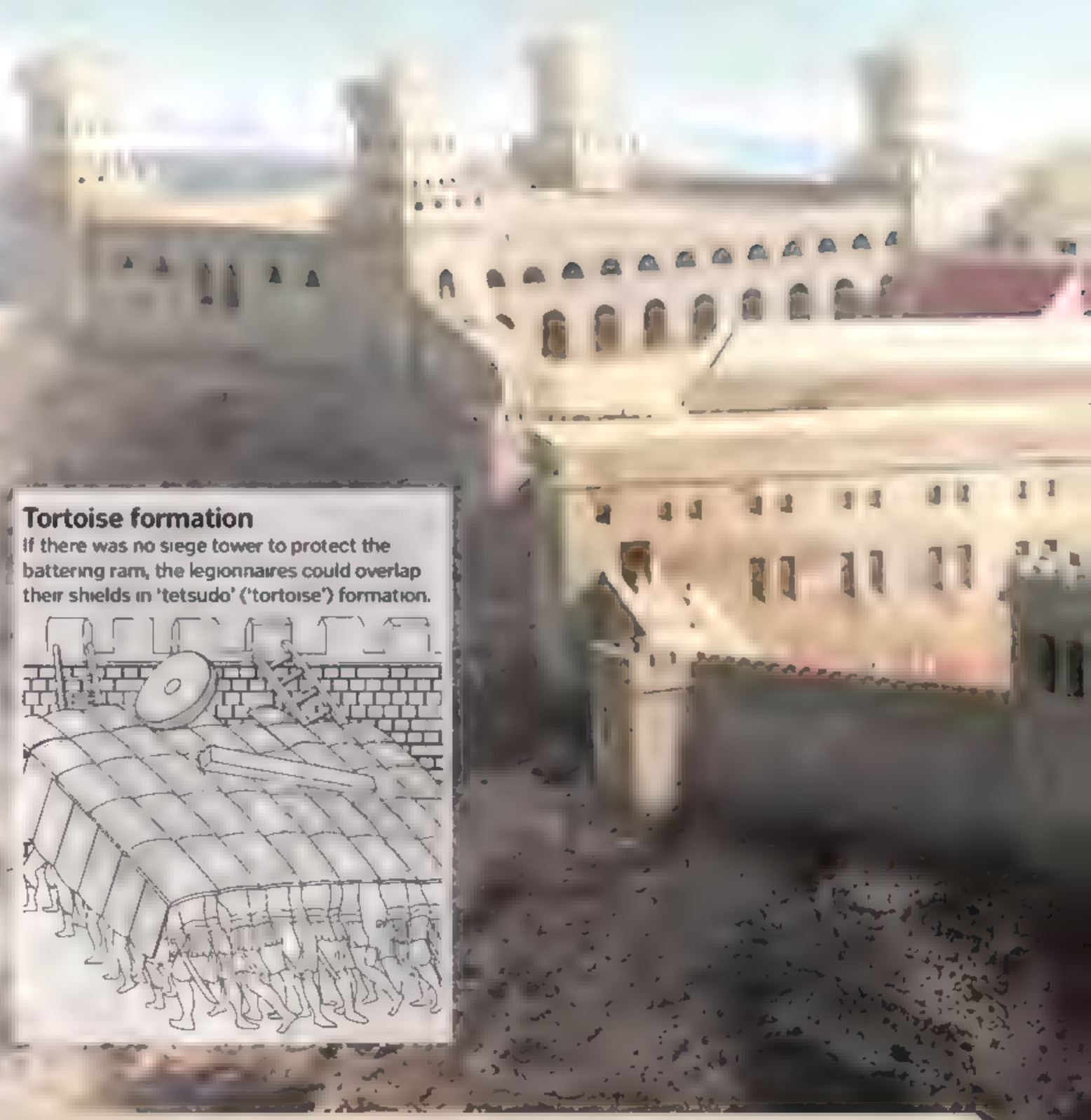
When it came to breaking down the walls to capture towns and forts – castles as we know them hadn't yet been invented – the Romans put all these things to the test, improving war machines invented by the Ancient Greeks and creating some of their own. The siege would first begin with the Romans setting up a camp with guard towers and fortifications of their own to cut off the enemy from reinforcements and food. The Romans would also try to cut off their foe's water supply by digging new channels to redirect rivers or by digging down to divert the flow of underground springs.

If hunger, thirst and despair didn't force the enemy to surrender, the Romans would then attack with various siege engines, such as wheeled towers that enabled men to storm directly over the defences across bridges. Battering rams and grappling hooks would knock or pull down walls, and catapults and ballistas would hurl rocks or iron bolts at the defenders.

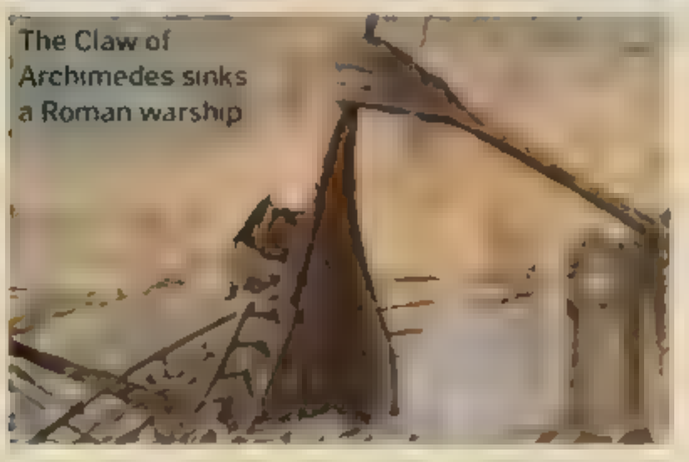
Engineering played a role too, as tunnels were sometimes dug under the walls, causing the foundations to collapse and bringing the wall crashing down with them.

Once the town or fort had been taken, the bloodshed wasn't over. Survivors were often killed, taken as slaves or had their right hands cut off so that they couldn't use weapons in the future. Under Roman law, as soon as the battering ram touched the wall the defenders lost all right to surrender. Can you blame any that gave up as soon as the Romans arrived?

Scorpion
Like a giant crossbow, the scorpion could fire an iron bolt up to 400m (1,312ft) with terrifying accuracy.



Tortoise formation
If there was no siege tower to protect the battering ram, the legionnaires could overlap their shields in 'tetsudo' ('tortoise') formation.


The Claw of Archimedes sinks a Roman warship

Heat rays and giant claws

If you thought Roman combat engineering was ingenious, the Siege of Syracuse (214-212 BCE) took it to a whole new level when Greek mathematician and inventor Archimedes counted himself among the embattled defenders.

As Syracuse (on the island of Sicily) was protected by the sea, the Romans brought a floating siege tower called a sambuca that lowered ladders onto the walls. Meanwhile, Archimedes deployed the Claw of Archimedes, which is described as a crane with a claw that reached into the water to tip over Roman boats. Legend has it he also used bronze or copper shields like mirrors to redirect the fierce Mediterranean sun and set fire to the enemy's sails.

Whether or not Archimedes actually did use a heat ray has been hotly debated since the Renaissance and there was no chance of the Romans clearing up the mystery as, against the orders of General Marcus Claudius Marcellus, the 75-year-old scientist was killed by a Roman soldier when the city fell.

THE STATS

BLOODIEST SIEGE 60,000-1,100,000 deaths

LONGEST SIEGE 8 years

LARGEST ARMY ASSEMBLED 85,000 to 110,000 men

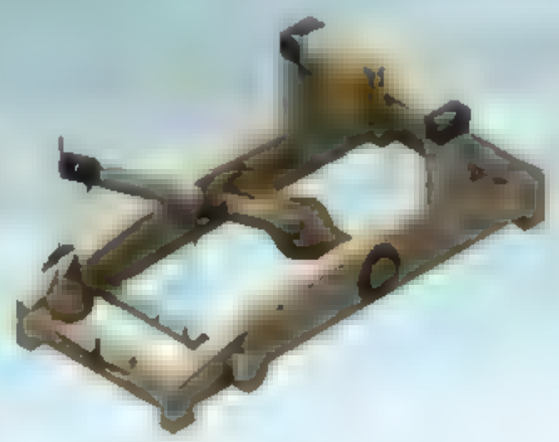
25% NUMBER OF SLAVES IN THE POPULATION

PEAK EMPIRE 5,000,000km²

PEAK (EST) POPULATION 70,000,000

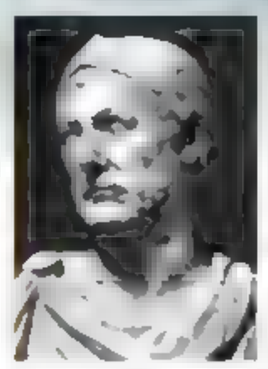
DID YOU KNOW?

Onager
Taking its name from the kick of a wild ass, this catapult could fling both rocks and clay pots filled with burning pitch.



Ballista
Similar to the scorpion, the largest ballistas were able to hit a range of up to 1,100m (3,609ft).

Food fight



No strangers to sieges themselves, the Romans weren't afraid of playing mind games to convince their enemies to give up the fight. When the Gauls – from what is now France – invaded Rome in the late-4th century BCE, they knew the only way they'd defeat the superior Roman garrison was to starve them out. In order to convince the Gauls that they had more food than they knew what to do with, the Romans threw loaves of bread down from the walls. When Hannibal laid siege to the Roman city of Casilinum in the First Battle of Capua in 212 BCE, he ploughed up the fields between his army and the city walls so that the defenders wouldn't even be able to chew on grass. To make Hannibal think they had enough food to last until the harvest, the gutsy defenders threw seeds down into the freshly ploughed earth.

Incoming fire
Rocks thrown by catapults often stood little chance of damaging the walls, but they could prove deadly to the men defending them.

Defenders
The only chance the defenders had of surviving a Roman siege was to keep the tower, ladders or ram away from the wall. . or simply surrender.

Archers
The men on top of the tower had to keep the defenders too busy to destroy the siege engines by peppering them with arrows.

Siege tower
The 15-25m (50-75ft)-tall siege tower protected the attackers from the enemy's arrows.

Dirt ramp
Unless the tower could get to the base of the wall it was useless and slaves were forced to pile up earth into a ramp called an agger.

Battering ram
A heavy iron ram's head on a wooden shaft could be swung from the base of the siege tower.

"The stone mined there was used to construct iconic Parisian buildings such as Notre Dame and the Louvre"

The Paris Catacombs

Why were over 6 million people buried deep beneath the city?

During the late-18th century, the people of Paris were running out of space to bury their dead. The Holy Innocents' Cemetery – the largest and oldest in the city – was literally bursting with corpses. In a bid to prevent further overcrowding, a radical solution was needed. Starting in 1786, corpses were gradually transferred to the labyrinth of tombs and antechambers some 20 metres (66 feet) under the capital. During the Reign of Terror, many "enemies of the revolution" executed by guillotine were buried direct in the Catacombs.

The site was originally an underground quarry and the stone mined there was used to construct iconic Parisian buildings such as Notre Dame and the Louvre. The location's transformation into the macabre subterranean ossuary we see today even brought with it grim notices etched above doorframes: "Arrête, c'est ici l'empire de la mort" ("Halt, this is the realm of death"). Mourners and intrigued tourists have visited the site since the early-19th century, and human remains were regularly transferred there until 1859.

The 'population' of the Paris Catacombs is more than of the living city above

How kilns work

Find out how bricks, mortar, pottery and more are made

In their simplest form, kilns are chambers – akin to an oven or furnace – that are heated to high temperatures in order to harden or dry certain materials. Such materials include clay, bricks and other building matter, which all require a certain level of durability in order to be effective.

For pottery, the temperature is slowly increased inside the kiln until the water trapped in the clay evaporates at about 100 degrees Celsius (212 degrees Fahrenheit), making it shrink but otherwise staying intact. As the temperature continues to increase, all traces of carbon and sulphur are burned off at around 800 degrees Celsius (1,472 degrees Fahrenheit). At temperatures above 900 degrees Celsius (1,652 degrees Fahrenheit) or so, the clay particles begin to fuse together. Some minerals in the clay will also start to melt, filling any gaps within the structure to make it stronger.

Two main types of kiln exist; continuous kilns are divided into zones of increasing temperature, while periodic kilns consist of a single chamber heated to the desired temperature.

Kilns have been used since ancient times to melt materials for tools and even to dry out foods

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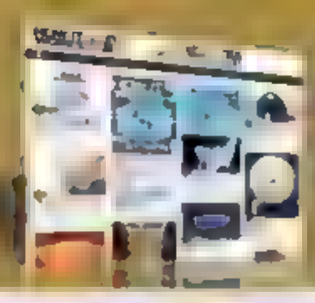

AMAZING VIDEO!

Learn about 19th-century Pullman sleeper cars

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DID YOU KNOW? ...ranged ...ed in a Pullman ... car after his death

On board the Pullman train

Why was the Pullman railway carriage fit for a queen?

The first half of the 19th century saw a rapid expansion in train travel with new companies and tracks springing up in the wake of Britain's first steam railway, linking the growing industrial cities of Liverpool and Manchester, which opened on 15 September 1830.

The Pullman Palace Car Company was established in 1862 in the United States, although specialising in sleeper cars (more popular in the US due to the greater distances) they began exporting passenger coaches to Britain 1874.

Far from being late to the party, Pullman quickly cornered the market on luxury. Appealing to the growing middle classes who had money to treat themselves, Pullman coaches offered leather seats, table lamps, dining cars, attentive stewards serving food and drink, and even heating and air conditioning. With the agreement of its American counterpart, a British company – the Pullman Car Company – formed in 1882 to produce similar carriages from a workshop in Brighton. The coaches and the service George Pullman would have recognised endured into the 1960s and 1970s, when classic Pullman coaches began to be replaced by designs fit for the age of diesel power and regular commuter travel.

An instantly recognisable symbol of a lost era of elegance, Pullman coaches have been used by the royal family and have even survived bomb damage during the second world war.

Pullman and civil rights

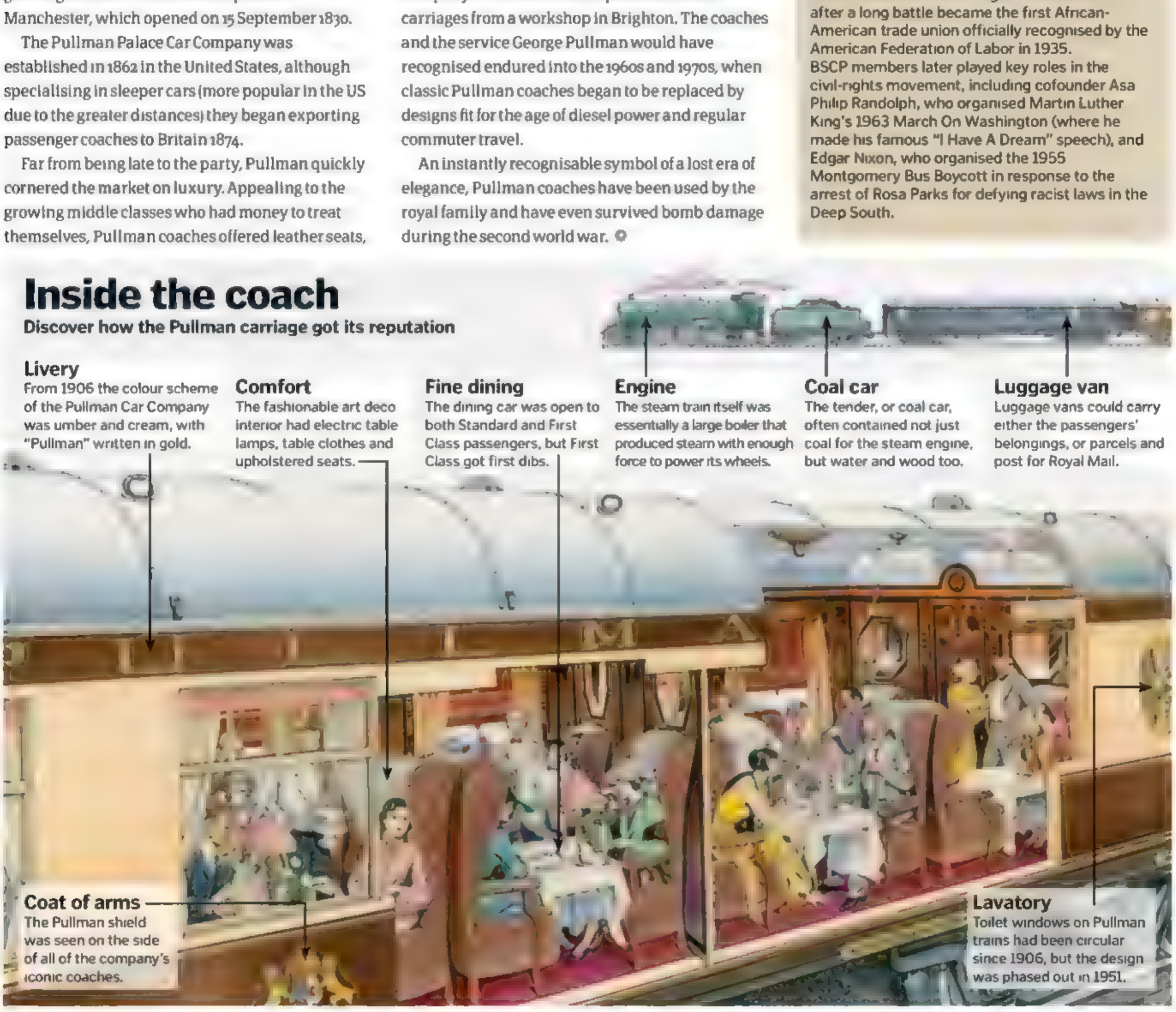
By the 1920s, the Pullman Palace Car Company had become one of the largest employers of African-Americans in the United States, but conditions were still poor for black porters who relied on tips from passengers for income and were denied promotion to jobs specially reserved for white employees.

On 25 August 1925, the Brotherhood of Sleeping Car Porters (BSCP) was formed with the motto "Fight or Be Slaves" and after a long battle became the first African-American trade union officially recognised by the American Federation of Labor in 1935.

BSCP members later played key roles in the civil-rights movement, including cofounder Asa Philip Randolph, who organised Martin Luther King's 1963 March On Washington (where he made his famous "I Have A Dream" speech), and Edgar Nixon, who organised the 1955 Montgomery Bus Boycott in response to the arrest of Rosa Parks for defying racist laws in the Deep South.

Inside the coach

Discover how the Pullman carriage got its reputation



"The job your parents had and how much money they made could determine the education you received"

What was school like 100 years ago?

In Edwardian England all children went to school but that didn't mean things were fair

By the first decade of the 20th century a lot had changed for children in England and Wales. In 1880 the Elementary Education Act made school compulsory for every child aged between five and ten, with the leaving age rising to 12 in 1899. In 1902 – the year after Queen Victoria's death – the Education Act gave local councils control of schools and another act in 1904 decided that secondary schools should teach the same core subjects. However, things were far from equal and in the early-20th century the job your parents did and how much money they made could determine the education you received.

The upper classes sent their children to private schools (also called public schools) that charged high fees but guaranteed their children would receive an education worthy of high society. Some schools even had their own cadet force to prepare the boys for careers as army officers. Meanwhile, public schools for girls trained them to become well-to-do wives and while the boys played rugby, their sisters would focus on how to be the perfect hostess.

Schools for the middle classes – the children of professionals and small businessmen – were similar, but the fees were lower and the school's reputation rarely meant the pupils could attend the best universities. Meanwhile, the children of the average working-class family attended free schools where going to university wasn't an option. Instead they learnt practical skills that would prepare the boys for manual work and the girls for housework.

Please Sir!

Discover the clothes and kit of the Edwardian schoolmaster

Mortarboard
The mortarboard was only worn by university graduates, making it more common on teachers in private schools.

Silk cravat
The silk cravat necktie was commonly worn by the Edwardian gentleman along with a waistcoat.

Pocket watch
Watches on chains were very fashionable for men and the most expensive were gold

Chalk dust
After writing on the blackboard all day, a few spots of chalk dust were inevitable.

Gown
Like the mortarboard, the gown was worn only by teachers who had graduated from university.

Dark cloth
Though not as sombre as the Victorians, Edwardian men stuck to dark colours.

Dunce cap
Students who made too many mistakes were humiliated by being made to wear a pointed 'dunce' cap.

Cane
The bamboo or rattan cane was used for pointing at the blackboard – and punishment, of course.

Canings and birchings

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MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford Uni and another in Real-time Computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

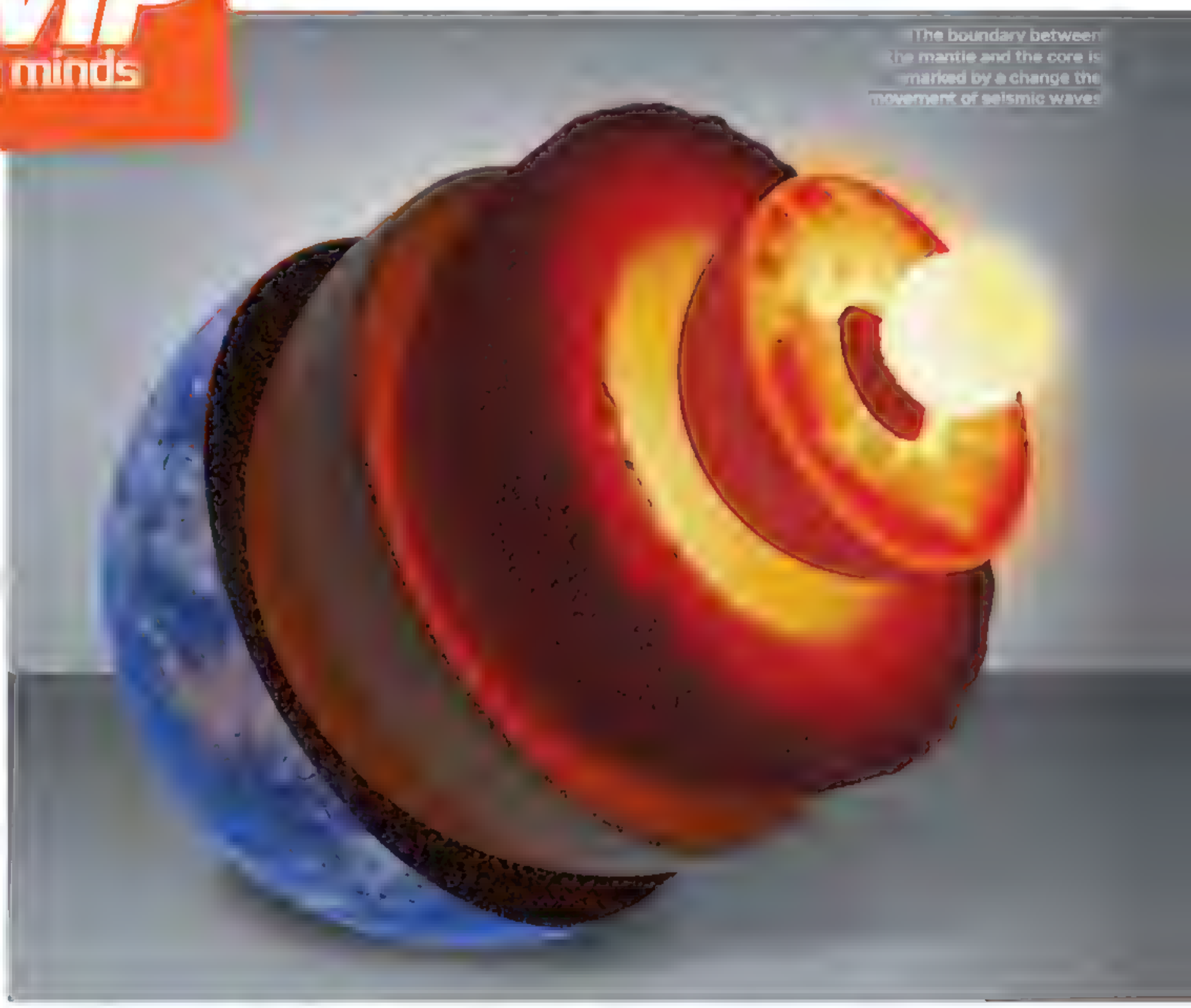
Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Hayley Peterek

When she's not out shooting a sunrise, writer and photographer Hayley is researching everything about space, smart animals and biology, among many other things. She thrives on discovering interesting facts about nature, science and tech.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!



Is there a boundary between the core of the Earth and the mantle?

Shelley Wasser

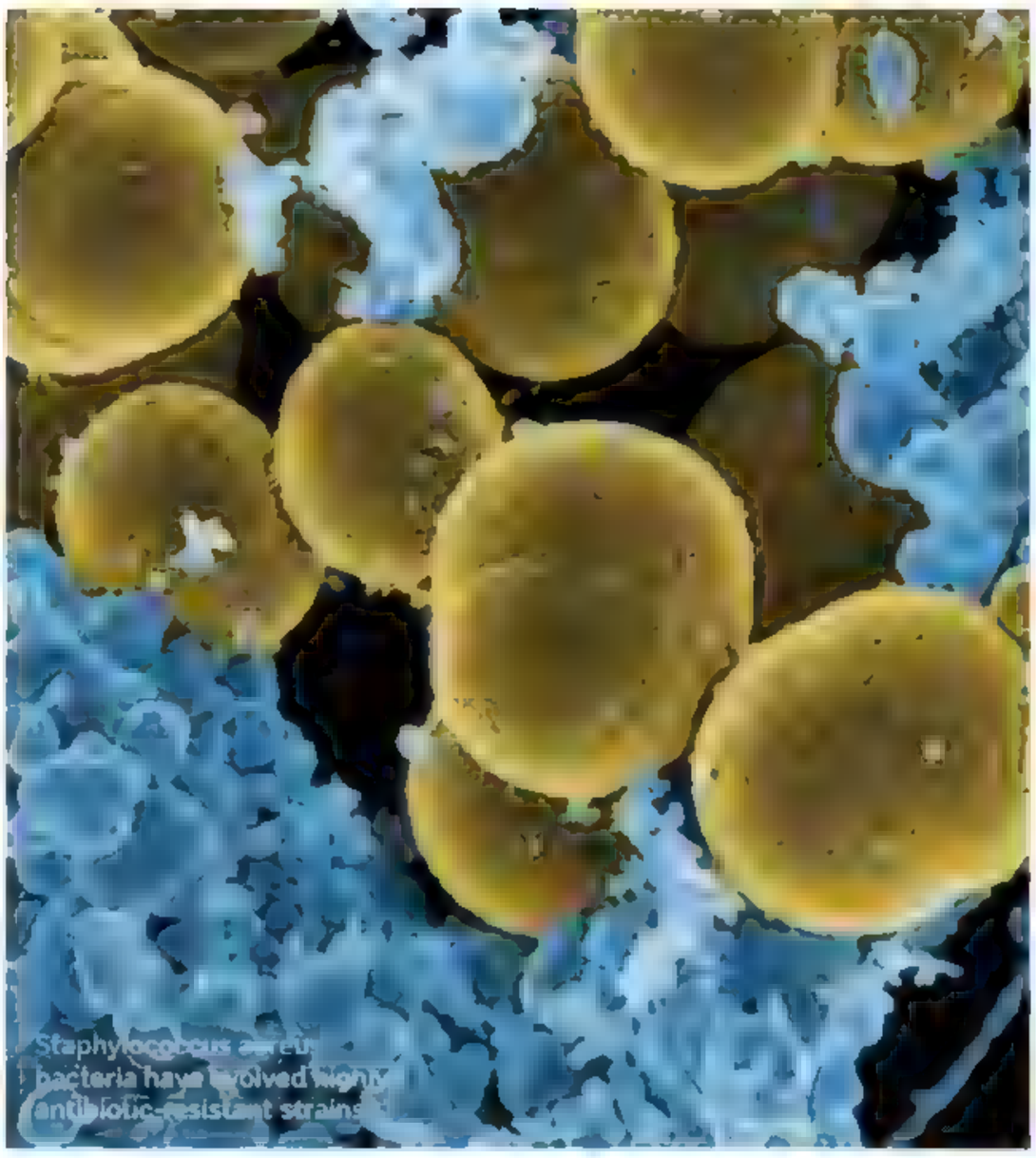
■ There seems to be a very definite transition at a depth of around 2,900 kilometres (1,802 miles), known as the core-mantle boundary. We don't know for sure what is going inside our planet, but by looking at how seismic waves travel through the Earth, scientists have a pretty good idea. Secondary seismic waves (known as S-waves) can't travel through liquids, and at the core-mantle boundary they abruptly disappear, indicating they have moved from a solid (the mantle) into a liquid (the core). The boundary region contains patches known as ultra-low velocity zones, which are thought to contain high levels of iron that make them very compressible, giving them their strange wave-slowing properties. **LM**

Do horse chestnuts really keep spiders away?

Sarah Harris

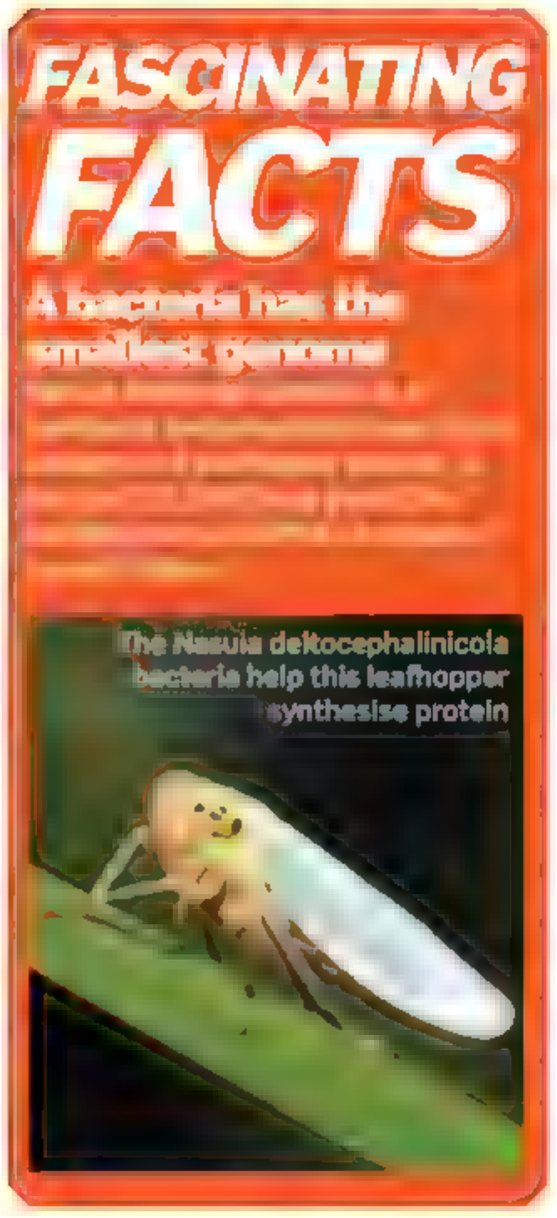
There is no evidence to back up the claim that conkers repel spiders. In 2009, the Royal Society of Chemistry (RSC) offered a prize to anyone who could provide proof of this old wives' tale. One theory was that a chemical in the horse chestnuts might smell unpleasant to the arachnids. But with nobody able to substantiate the claim, the RSC concluded it was false, awarding its prize to schoolchildren who had conducted a number of experiments suggesting spiders were indifferent to horse chestnuts. Instead, lemon juice or essential oils may be a more effective natural spider repellent. **AC**

How do we become resistant to antibiotics?



Karen McAvoy

■ It's not us that become resistant, it's the bacteria we are trying to kill. Bacteria multiply quicker than other organisms and have simpler genomes, so random mutations happen more often. Some of those might give them a tougher cell wall or a way to metabolise a toxin. Low doses of antibiotics given to farm animals, and as medicine to humans who don't really need it, provide an environment that only kills the weaker bacteria. The ones that are left are those with the genes for antibiotic resistance, so they go on to multiply and spread those genes. **LV**



Why do cats always land on their feet?

Jonathan Gray

■ When they take a tumble, cats move their front and back limbs separately to create spin (angular momentum) and right themselves in mid-air. This feat requires great flexibility. First, a falling cat uses its eyes and inner ear to work out which way is down. It then stretches out its hind legs while pulling in its front legs. Turning its rear end slightly one way, it twists its front end in the other direction until its front paws are facing down. From this position it tucks in its back legs and swivels them around, enabling it to stretch out all four limbs toward the ground. **AC**

Why is seawater salty?

Sharon Li

■ Most of the salt in the ocean comes from a process that takes place on land. Rainfall contains carbon dioxide from the atmosphere, making it acidic. As the rain erodes rocks on land, it releases ions – atomic particles that carry an electric charge. Rivers and streams eventually carry these dissolved ions out to the ocean. Some are removed from the water by various plants and animals, while other ions – mainly sodium and chloride – remain and become more concentrated. These two ions are what make seawater salty. It's estimated that if all of the oceans were evaporated and their salts were spread evenly on the entire surface of the Earth, it would form a 152-metre (500-foot)-thick layer. **SF**

Seawater can be evaporated to harvest the salt for culinary or industrial purposes.

Why do my joints crack so often?

Samuel Lloyd

■ There are a few different reasons why your joints may crack. Joints are lubricated by a fluid called synovial fluid, which contains gases like carbon dioxide, nitrogen and oxygen. When you move the joint, gas bubbles are quickly released and make a popping sound. Popping noises may also come from tendons and ligaments moving or tightening as the joint moves. Sometimes joints crack more often after surgery or if you have arthritis, which can cause rough joint surfaces and worn cartilage. Despite what you may have heard, cracking joints don't indicate a problem unless they're also accompanied by pain, swelling, or loss of function or motion. Purposely cracking your knuckles, however, may lead to swollen joints and a weaker grip. **SF**

BRAIN DUMP

What's the difference between horns and antlers?

Stacey Wood

Horns, unlike antlers, are a permanent fixture, and are really an extension of the animal's skull. They are typically found on bovine animals like cattle, antelope and bison. Most horns are made up of bone surrounded by proteins and keratin, the same stuff from hair and nails are made of.

Antlers on the other hand, which are commonly sported by male deer, reindeer and moose, will grow and shed seasonally in order to attract a mate and ward off potential competition during the mating season. They grow from the pedicle which is positioned above the animal's skull, and are made up entirely of bone. **HP**

How does salt melt ice on the roads?

Olivia Edwards

We spread granulated salt on icy roads because it lowers the freezing and melting temperature of water. When water cools to zero degrees Celsius (32 degrees Fahrenheit) or below, it freezes into ice. But when you add salt, the water must be at a much lower temperature to freeze. For example, a 20 per cent salt solution would freeze at -16 degrees Celsius (three degrees Fahrenheit) instead. If you sprinkle salt on ice that's formed on the road, it will dissolve into the liquid water film on the surface of the ice and ultimately melt it.

There is a limit, however; if the road temperature is lower than minus-nine degrees Celsius (15 degrees Fahrenheit), the salt cannot penetrate the surface of the ice to begin the process of melting it. Some places add calcium fluoride to their road-salt mixture at these colder temperatures, which allows for melting at slightly lower temperatures. **SF**

Why is glass transparent?

Olivia Edwards

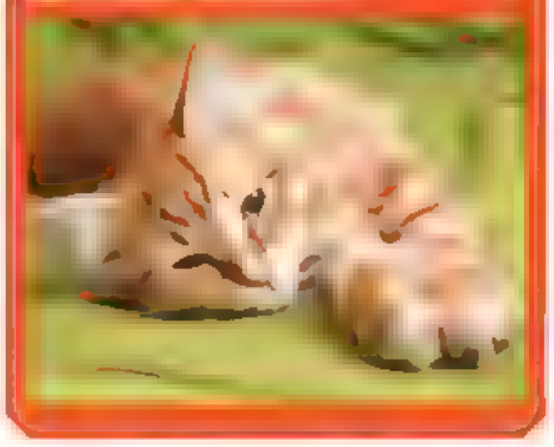
Let's consider the opposite situation first. When light strikes something opaque, such as a brick, the photons interact with the electrons of the atoms in the brick. The energy in each photon can promote an electron to a higher energy level, but the laws of quantum mechanics say that it's all or nothing – the electron must jump all the way up to the next energy level or stay where it is; there is no in-between. If the photon has the right energy, the electron jumps up a level and the photon is absorbed. In brick and most other materials, that's easy to do, because the next energy level is in easy reach, and so most photon wavelengths are absorbed. Glass just happens to have a big gap up to the first available energy level and the photons in visible light don't have enough oomph to boost the electrons this high, so they pass straight through. **AC**

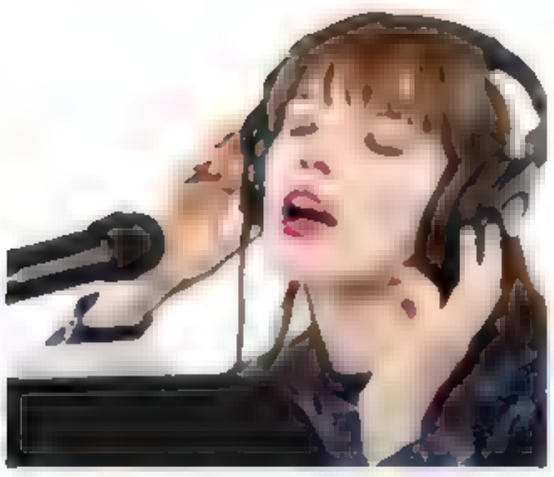
FASCINATING FACTS

The first-ever photo was taken in France

Denmark's flag is the world's oldest

Cats are the world's favourite pet

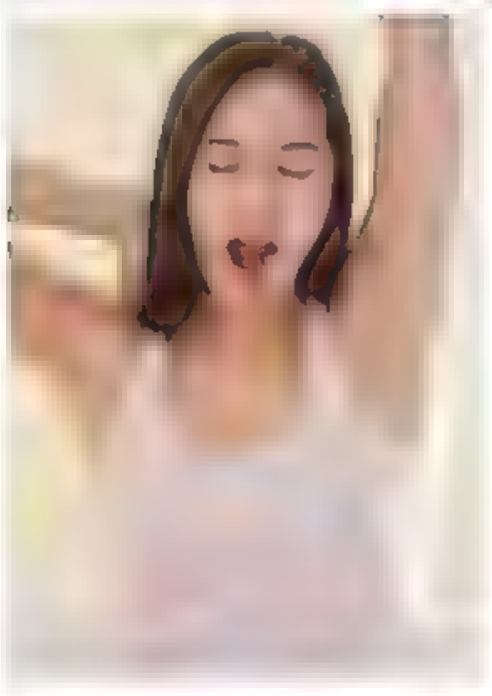




Why does my voice sound different on a recording?

Megan Watson

A recording only captures part of the sound of your voice – the part that travels through the air to the microphone. This is the same as the sound that reaches the ears of everyone else, so the recording sounds just like your real voice to them. But when we normally hear our own voices, the sound is a combination of this airborne sound, and the sound that travels through the bones of our jaw and skull. This favours the lower sound frequencies, so we all hear our voices as deeper and more resonant that the rest of the world does. **LV**



Why do we yawn?

Jesse Peters

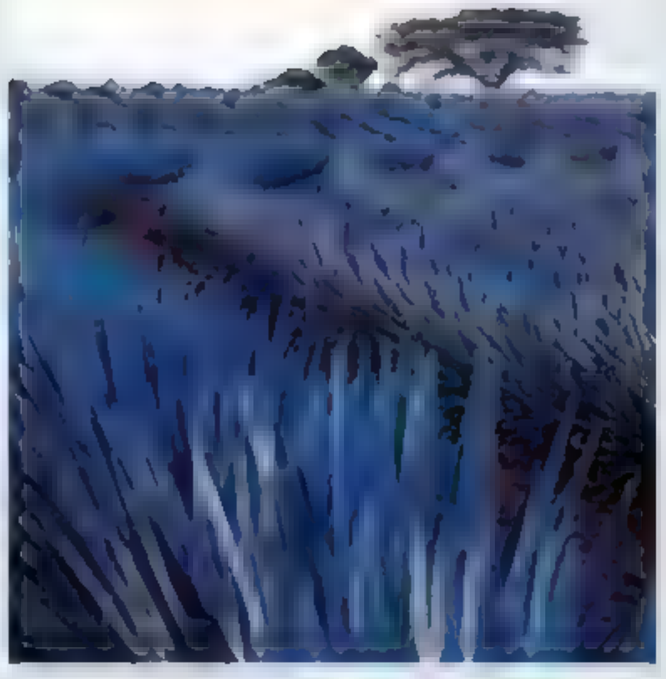
Yawning involves a deep, involuntary intake of breath, and until recently, the most popular explanation was that it increased the supply of oxygen to the brain However, this idea didn't hold up to testing, and there is mounting scientific evidence to suggest that yawning has more to do with temperature than with oxygen. As brain temperature rises, concentration and memory suffer, and a number of different tests in humans and animals have shown that yawning is actually linked to heat, and increases when our brains are getting too warm. The idea is that by taking a deep breath of cool air, brain temperature drops back down, increasing alertness. **LM**

How is tequila made?

James Driver

Tequila is only produced in the region of Tequila in Mexico. It originates from the blue agave plant, which can take between eight and ten years to fully mature. Once ripe and ready for harvesting, the agave's core, known as the piña, is extracted. A piña can weigh over 90 kilograms (200 pounds) and each litre (0.26 gallons) of tequila requires around seven kilograms (15 pounds) of piña to produce

At the distillery stage, the piña hearts are split open and roasted in large ovens, in order to break their complex starches into sugars. The released liquid is then sealed within large steel vats for fermentation where yeast is added. Fermentation can last hours or even days and the fermented juice, or mosto as it's known, will have a low alcohol content at this stage. In order to increase the volume of alcohol, the mosto is distilled twice, by heating the liquid to alcohol's vaporisation point before cooling and condensing it. Purified water is then added to dilute the tequila for a 40 per cent alcohol content, and it is either bottled immediately or transferred to wooden barrels in order to age for up to three years. **HP**



Why do stars twinkle?

Tom Wilkinson

Stars twinkle when it appears there are variations in their brightness. Astronomers call this phenomenon atmospheric scintillation, and it's caused by motion in the atmosphere. Specifically, changes in atmospheric temperature cause small fluctuations in the air's density. As starlight passes through the atmosphere, it's refracted, or slightly alters direction, creating a twinkling effect. Atmospheric scintillation is more obvious when viewing stars closer to the horizon, because there's a thicker layer of atmosphere. Astronomers compensate for atmospheric scintillation by using special adaptive optics on the most sophisticated telescopes. Space-based observatories like the Hubble also allow us to view stars and other objects without atmospheric scintillation. **SF**

BRAIN DUMP

What are sinkholes?

Andy Madden

Sinkholes form when water slowly erodes the bedrock underground, until the surface is no longer supported and collapses into the cavity beneath. This occurs most commonly in areas where the bedrock is made of salt or carbonate rocks (such as gypsum or limestone), which are particularly susceptible to dissolving. In the absence of surface drainage, water accumulates in the sinkhole, draining through to the subsurface. Cover-subsidence sinkholes create a small depression at the surface, which sinks slowly. Cover-collapse sinkholes are far more dramatic, collapsing in a matter of just a few hours and potentially causing catastrophic damage. One of the most spectacular sinkholes ever seen opened up in Guatemala City in 2010, swallowing a three-storey building. It measured 20 metres (66 feet) across and had a depth of 30 metres (98 feet). Sinkholes are a natural phenomenon, but manmade changes to drainage flows (such as ground pumping) or land use changes can encourage them to occur. **AC**

FASCINATING FACTS

How heavy is a cloud?

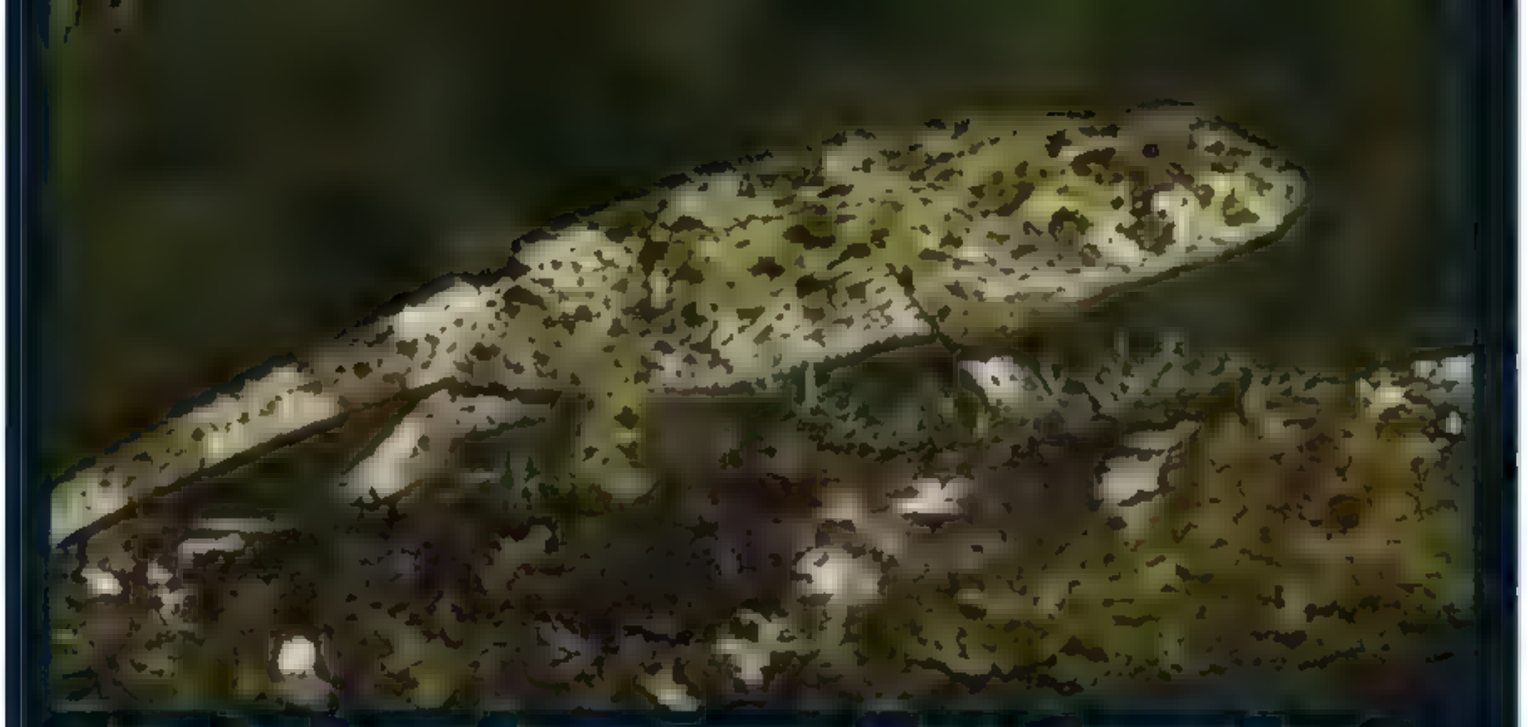
Ryan Jessop

If you consider the weight of the water droplets the average cloud contains, it weighs in at around 500 tons. Clouds are made up of tiny droplets of water or ice crystals, suspended in the air. On average, a cumulus-type cloud – the white, fluffy type – has a volume of one cubic kilometre (0.24 cubic miles), containing 0.5 grams (0.018 ounces) of water per cubic metre (35 cubic feet). This adds up to a total of 500 tons, although in reality this can vary significantly based on the size of the cloud. Despite this huge weight, clouds still float because the dryer air below them is denser. **AC**

Why are mice typically used for animal testing in labs?

Harold Banks

Mice are convenient because they are small, easy to keep and quick to breed. They are mammals like us and have 99 per cent of the same genes as us. Mice have been used for long enough now that there are lots of mutant varieties commercially available to researchers that allow them to simulate various human diseases or quickly stimulate the growth of cancer tumours. Testing medical treatments on mice is generally considered more ethical than using highly experimental drugs on humans, but it is only a first step. Many drugs that cure cancer in mice have turned out to be less effective in humans. **LV**



How do chameleons camouflage themselves?

Bernard Carr

Certain species of chameleon have layers of cells called chromatophores, which contain different-coloured pigment granules; by moving these granules around, they are able to control their colour. However, this technique is more commonly used as a method to signal emotions than for camouflage, and the species with the best colour-changing abilities tend to use their talents to attract a mate rather than to hide from predators. For most species of chameleon, camouflage works in a similar way to camouflage in other animals, and they have evolved over time to blend in with their surroundings. For example, the mottled colour and spiky shape of the brown leaf chameleon make it almost invisible among dead leaves. **LM**

What causes lens flare in photos?

Beth G

Lens flare can be problematic as it's capable of drastically reducing contrast in an image as well as introducing halos and scattered polygonal shapes across the frame. That being said, many photographers opt to include lens flare in their photos for artistic effect. It occurs when a bright light, such as from the Sun, hits the surface of the lens at an unusual angle, as opposed to straight on. This strong stream of light will then reflect and bounce off multiple elements within the lens before finally reaching the sensor where it will be recorded as part of the picture. **HP**

How many people are in the average family tree?

Douglas Burns

This depends on how far back you look, and what you think of as an 'average' family. The number of children per family varies widely from country to country and from generation to generation. For example, in the UK, the average number of children in each family in 2012 was 1.7, while in the 1970s it was 2.4. Worldwide, the figures were 2.5 children in 2012, compared with five in 1960.

As you can see, it is hard to define the 'average' family tree. However, there is one universal truth about families – everyone has two biological parents – so you could ask, how many ancestors do I have?

You have two parents, four grandparents, eight great grandparents, 16 great-great grandparents, and so on. For every generation you add double the number of ancestors as the previous generation. Assuming the average generation length is around 25 years, if you go back just 250 years in history, your family tree will contain around 2,047 people. **LM**

Why does chopping onion make your eyes water?

Paula Winger

Crying over a cut onion is commonplace in the kitchen, but it's all down to a unique chemical reaction. In fact it starts underground, as a growing onion will naturally absorb sulphur from the earth, creating molecules known as sulphoxides to form. When you cut into an onion with a kitchen knife, you're essentially breaking into its cells, which release certain enzymes. These enzymes react with the sulphoxides, converting them into sulphonic acids. This powerful combination results in the release of a vapour that will irritate your eyes. In order to flush out the irritation, nerve endings in your cornea will inform your brain of the aggravation, which in turn will instruct the lachrymal glands above your eyelids that can regulate the release of tears, to flush it out by making you cry. **AC**

New Brain Dump is here!

Don't miss issue 22 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 1 March. Inside you'll discover the answers to curious questions like: Why do dogs chase sticks? Why is salt bad for the heart? And where do bird feathers get their colour from? You'll also learn all about the human eye, as well as how to build a nest box. Every issue is packed with stunning images and fun facts to entertain your friends and family with. Download the new issue of **Brain Dump** on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is **@BrainDumpMag**

Drones

Get a new perspective with your own mini drone

Drones come in all shapes and sizes, from the big, expensive professional models used by filmmakers, to the cheap and cheerful toy versions that anyone can have a go with. However, it's not just the high-end drones that feature built-in cameras, as most mini quadcopters now give you your own first-person view (FPV) from the air too.

Checklist
- ✔ Rolling drone
- ✔ Micro quadcopter
- ✔ Live streaming aircraft

Working range
The drone has a range of 80m (262ft), depending on the strength of your Wi-Fi signal.

1 Training wheels
Parrot MiniDrone Rolling Spider
£89.99 / $99.99
www.parrot.com
The ideal drone for beginners, Parrot's Rolling Spider comes with a set of detachable training wheels that not only help to protect it from knocks and bumps, but also enable it to drive up walls and over ceilings. It connects instantly via Bluetooth to a free app on your phone and is incredibly stable and easy to control.

The app interface is intuitive with simple controls, but the drone is frustratingly unresponsive at times, making quick manoeuvres extremely difficult. Plus, with just an eight-minute battery life, the fun is over quite quickly, and charging it up again can take up to 90 minutes.

Verdict: ●●○○○

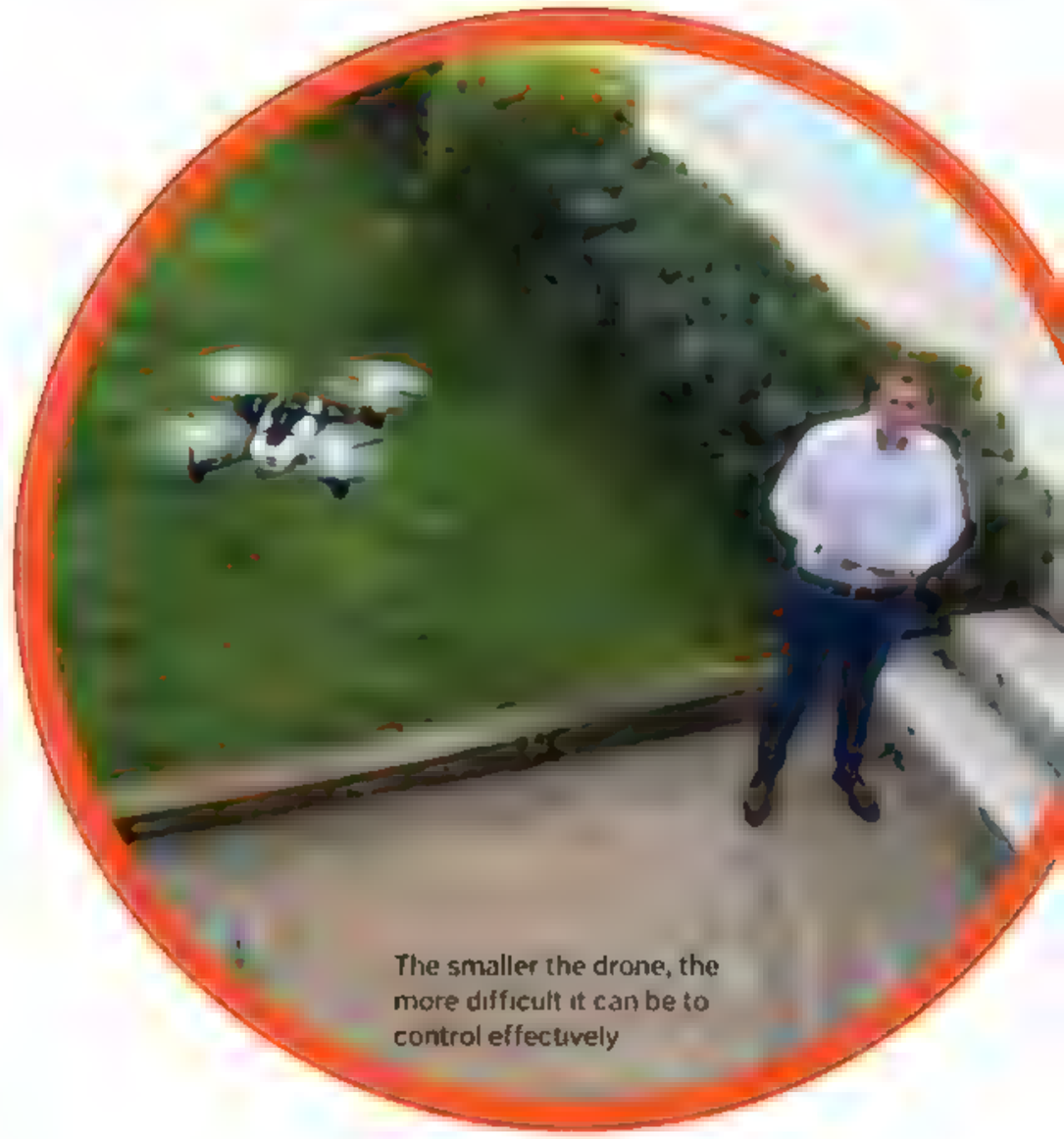
2 Pro controller
Hubsan X4 H107D
£159.99 / $249.99
www.ondrone.com
Although it's probably the world's smallest FPV quadcopter, the Hubsan X4 H107D is controlled via a bulky transmitter unit twice the size of the drone. The controller does connect instantly with the drone however, and features a 10.9-centimetre (4.3-inch) display that shows a live, if glitchy, view from the camera and records it to an SD card. The drone itself is very difficult to control, zooming off in random directions without warning, but it is hardy enough to survive the inevitable crashes. It's also incredibly noisy, but this, combined with the very bright LEDs, at least means you always know it's coming.

Verdict: ●●○○○

3 In-app streaming
Walkera QR W100S
£89.99 / $139
www.ondrone.com
The slightly bigger Walkera QR W100S may look more robust, but a simple landing caused a leg to snap off during our test. Despite not being very strong, it is a little easier to control than the Hubsan, and less noisy too. Before you can start flying, it must be manually connected to your phone via Wi-Fi. The free controller app is very basic, with a simple interface and limited range of features. However, it is more responsive than the companion app for the Parrot drone, and simply tilting your phone lets you change the drone's direction. You still only get about seven minutes of flying time from a single charge, though.

Verdict: ●○○○○

The built-in camera can take 300,000px photos but unfortunately cannot record video.



The smaller the drone, the more difficult it can be to control effectively

Battery life
The battery lasts for about seven minutes and takes 30 minutes to recharge fully.

EXTRAS

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Incredible Flying Machines

APP
FreeFlight 3

WEBSITE
DroneFlyers.com

Soundbars

Which of these speakers can offer the best sound quality?

1 Libratone Diva

Price: £649.95 / $N/A
Get it from: amazon.co.uk

Libratone has branched out from music, and the Diva is the company's first TV soundbar. After testing out the speaker for both, though, it's clear that Libratone has used all of its audio experience. The balance is good and clarity is impressive, although it's less powerful than the Sonos when it comes to deeper, bassy sounds. It has plenty of connection options, too – a digital input, a 3.5mm jack and wireless connection giving you a lot of choice. A companion smartphone app lets you customise sound, although it's a little limited. Still, we found it was incredibly straightforward to set up on the iPhone.

The Diva doesn't skimp on style, either – the wool covering of the speaker feels and looks great, and is customisable. The black option is standard and looks lovely, but you can pick from plenty of colours to match the décor of your front room. The rest of the speaker is plastic, but the build quality is excellent – it feels sturdy and the included stand and wall mount feel incredibly reliable.

If you're just looking for a soundbar to improve the audio of your TV and movies, there are admittedly better options. But for sheer style, sound quality and adaptability, the Diva certainly won't disappoint.

Verdict: ●●●●○

Smart but well formed
This is the smallest soundbar in our test, but still looks good and does the job nicely.

2 Roth Sub Zero II

Price: £149.99 / $N/A
Get it from: amazon.co.uk

This straightforward speaker is small and compact, but does a surprisingly good job of improving the audio of your TV. Considering its size, we were surprised by the audio quality – there is no bundled sub, but the soundbar still managed impressive balance. It's not as good as the Libratone or Sonos, but we preferred it to the Otone's overpowered bass.

And while the Sub Zero II won't be winning any design awards, we have to say we liked its minimalist appearance. The speaker is long, thin and not too tall, and it fitted better than any other speaker underneath our TV.

Connection options are good, with digital, analogue and Bluetooth all covered. The Bluetooth was very simple to set up and within seconds we were playing music wirelessly from our iPhone. The resulting sound was a little tinny, especially after we'd tested the Libratone Diva, but we weren't disappointed. Dedicated buttons on the included remote allow you to switch between TV, Movie and Music modes, and picking the right one helps to get the best results.

It can't beat the adaptable Sonos or Libratone, but if you're on a budget this soundbar is a great choice.

Verdict: ●●●●○

3 Otone SoundBase

Price: £129 / $N/A
Get it from: otoneaudio.co.uk

The Soundbase from Otone takes a different approach to TV audio than the other three on test here. It is designed to have your TV sitting on top of it, with two front-facing speakers under a stylish pyramid-studded front grille and a woofer in the bottom of the casing.

This is used to full effect when you connect the speaker. Bass is powerful, but if you want even more there is a Bass button on the included remote to ramp it right up. Unfortunately, doing this makes everything else sound muddy, and the lower tones sounds a little 'boomy' – we left it off after only a few minutes.

Still, the connection options are good, with digital, analogue and Bluetooth on offer. Bluetooth is just as easy to set up as with the Roth, but sadly the results aren't quite as good.

Our biggest problem with the SoundBase was the build quality. Yes, it's the budget option, but the whole thing felt cheap. The Roth soundbar is only £20 more, but looks great and feels much more sturdy than the Roth.

If you're in the market for better sound, this isn't the best choice – spend a little more for a much better sound.

Verdict: ●●●○○

4 Sonos Playbar

Price: £599 / $699

Get it from: sonos.com/shop

The first thing you'll notice about the Playbar from Sonos is its build quality. The mix of metal and cloth feels wonderful, and looks even better. We love the design of the Libratone, but Sonos has definitely beaten Diva for understated style.

The Playbar setup is the most complex of the four on test – to get the most from the speaker you'll need to connect it to your router via an Ethernet cable or add a £39 ($49) Sonos Bridge to your home network. Once connected, you can download an app to your smartphone to finish the process. You'll then be able to control the volume, equaliser and much more from your phone via the Sonos app, which also offers plenty of music to stream. It's not quite as simple as the Libratone setup, especially if you have an iPhone, but it still works nicely.

Once you're connected, you're treated to fantastic sound. Whether it's movies, TV or music, the Playbar does a wonderful job of bringing you right into the action. Bass is powerful but not overwhelming, speech is clear, and the balance when playing music is fantastic.

It's certainly expensive, but for an excellent all-round audio experience, the Sonos Playbar is unmatched by the other three.

Verdict: ●●●●●

ON THE HORIZON

Soundbars that take audio to the next level

Dali Kubik One

This huge, powerful soundbar offers a frankly insane number of connections. It's expensive, but it looks fantastic and offers a premium-quality audio experience.

Samsung Curved 8.1 Ch 320W Bluetooth Soundbar

If you've got a curved TV, this is the best option for you – the curved bar ensures the sound is fired straight at you, as well as sideways for surround sound.

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Make your own compost
Turn your garden waste into nutritious plant food

1 Pick a good spot
The ideal area for your compost heap should be a patch of soil that gets plenty of direct sunlight, as heat aids the composting process. You could buy a compost bin, or section off an area using wire mesh or planks of wood. It should be about 0.9 metres (three feet) tall by 0.9 metres (three feet) wide by 0.9 metres (three feet) deep, creating an area 0.7 cubic metres (24.7 cubic feet) in size.

2 The first layer
Start your compost heap with a layer of brown material high in carbon. This could include dead leaves, branches, twigs, wood chips, coffee filters, shredded newspaper, cardboard, sawdust and hay. Make sure larger pieces of material are chopped or shredded to allow for good airflow at the bottom of the pile. You could also add a little soil or manure to help kick-start the whole composting process.

3 Add more layers
Add a layer of green material rich in nitrogen to help generate heat. This could include grass cuttings, leaves, weeds, fruit and vegetable scraps, eggshells, tea bags and coffee grounds. Break up any large clumps of green material to allow air to circulate and then repeat the process until you have alternating layers of brown and green material. The ideal mixture should be three parts brown to one part green.

4 Keep it moist
Between each layer, sprinkle your compost heap with a little bit of water. You should add just enough to make it damp, but not so much that it becomes too soggy, as this will drown out the microorganisms, cause the material to rot and leave you with a useless, slimy mess. In really hot weather, you could cover your compost heap with a lid or sheet to keep the moisture in.

5 Turn the mixture
Once every one or two weeks, use a pitchfork or spade to turn the mixture and introduce oxygen. This will encourage aerobic decomposition, speeding up the composting process. As the microorganisms break down the material, they will also produce heat, so you may notice your compost heap start to give off steam. After about three months, the compost should be dry, crumbly and no longer giving off heat, meaning it is ready to use.

In summary...
With the right mixture of nitrogen, carbon, air and water, microorganisms use oxygen to break down plant matter and create carbon dioxide, heat and compost in a process called aerobic decomposition. It's a great way to recycle garden and food waste and will keep your beautiful garden plants happy too.

Create your own lava lamp

Use household materials to produce mesmerising colourful bubbles

1 Pour in some oil

Empty and wash out a clear plastic bottle, then fill it until it is about three-quarters full with vegetable oil. Oil is nonpolar, which means its molecules have neither a negative nor positive charge. The molecules are also not packed very tightly together, meaning the liquid is not very dense. Both of these factors are important for creating the lava-lamp effect as they cause the oil to react in an unusual way with the next ingredient.

2 Add water and colouring

Fill the bottle up with water and a few drops of dark food colouring. It will sink to the bottom because its molecules are packed more tightly together, making it denser and thus heavier than the oil. Each water molecule has two positively charged hydrogen atoms and one negatively charged oxygen atom, so it is polar and will attract the opposite charge of other molecules. Because oil molecules are nonpolar and have no charge, the two remain separate.

3 Create some fizz

Break up an alka-seltzer or other form of effervescent tablet into small pieces and drop them into the container. The citric acid and sodium carbonate in the tablet will react with the water to form sodium citrate and carbon dioxide gas. These gas bubbles stick to the water and travel upward because they are less dense than the oil. When they reach the top, the bubbles will pop, allowing the carbon dioxide gas to escape and the dense water to sink back down to the bottom.

In summary...

This fun experiment is a great way to learn about density and polarity. To create a permanent lava lamp, you'll need two liquids with much more similar densities and a powerful lamp to heat up the denser liquid so that it rises and then falls again when it cools down.

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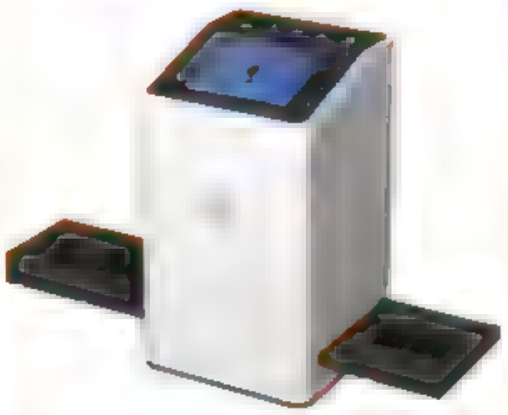

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Letter of the Month

Google Glass laws

Dear **HIW**,

With Google Glass coming out earlier last year, I was thinking about the way technology is passively being developed to destroy our social concept of privacy. For example, one of the most advertised features of the tech supergiant's new product is the ease of access of its camera and video technology. It uses simple voice commands to start these functions, which could be abused by some people. People often wouldn't know whether they are being filmed or pictured, a huge invasion of their privacy. The combination of smaller cameras and less noticeable controls being developed is a scary thought. Some game headsets even go so far to use electrodes to use 'mind-reading' tech as controllers

If this tech keeps being developed, we could find ourselves in a *Big Brother* world. Although this is incredible technology and I do believe it should be out there, I am very concerned that it is not being monitored and limited. Is there any legislation out there limiting how much this kind of technology can be developed, who can access it and how it should be used?

Alex Osborne

Hi Alex,

Although Google has now taken its hi-tech glasses off sale to continue development, they will definitely return at some point in the future, and of course some people still own the original version.

There are currently no rules on the development of this technology and Google Glass was and will again be available to anyone who has enough cash to spare, but there are some restrictions on how it can be used. For example, in the UK, the Information Commissioner's Office has stated that Data Protection Act rules apply. This means that if users want to use the data they record for anything other then personal use, they must make sure people are informed about how their details are being collected and used, only collect information that is relevant, adequate and not excessive and ensure that information is kept securely and deleted once it is no longer required.

It's true; holding your nose and humming at the same time is impossible

Humming science

Dear **HIW**,

I am a subscriber to **How It Works** and I was just wondering how come we cannot hum while we are holding our nose? I hope you get to answer my question in the next magazine. I really enjoyed the latest issue about the drones and I recently bought one of them featured in your article.

Yours sincerely,

Alasdair Ager

This is one of our favourite weird facts, Alasdair, and we've definitely had a go at trying it. The science behind it is surprisingly simple though. To make a humming noise, air needs to pass over the vocal cords in your throat to make them vibrate. When you hum, you typically have your mouth closed, blocking air from coming in or out, and if you hold your nose closed too, air can't travel through there either. By blocking both of these paths, you stop any airflow, so your vocal cords can't vibrate and produce sound.

Aeroplane trails

Dear **HIW**,
I have enjoyed your magazine for just over a year now, and on reading an article in your latest issue I have remembered a question I have always wanted to know the answer to: What is the 'cloud' that you can see trailing behind an aeroplane?
Thank you,
Ben Fuller

The process that produces the white trails (called contrails) behind an aircraft is similar to the one that enables you to see your breath on cold days. As the hot and humid exhaust fumes from the plane's engines mix with the cold air, they condense and freeze around particles of the aerosols in the fumes to form clouds. Contrails can even be used to predict weather, as a thick, long trail suggests humid air at high altitudes, which is often an indicator of an oncoming storm.

Driverless car rules

Dear **HIW**,
I would just like to say what a great magazine **How It Works** is and that I have learnt so many different things from it. I loved reading about the driverless cars in issue 65, but what would happen when two cars meet on a byroad, would they both reverse, which one would reverse or would all roads be made to main roads?
Thanks
William Tucker (age 14)

As driverless cars don't tend to come into contact with each other very regularly, we don't really know the answer to this yet. However, as more and more driverless cars like Google's take to the road, it's likely they will all be able to communicate with each other via wireless signals to decide who has right of way.

Audi's RS7 driverless car has precise sensors that help it to make decisions autonomously

What's happening on... Twitter?

We love to hear from **How It Works'** dedicated followers. Here we pick a few tweets that caught our eye this month

[redacted]
Yay, new @HowItWorksmag! #Brainfood

[redacted]
@HowItWorksmag Happy to say my copy arrived this morning along with @AboutHistoryMag, great magazines! Thanks

[redacted]
So that has just blown my mind. Would like to be brought back to life to read @HowItWorksmag

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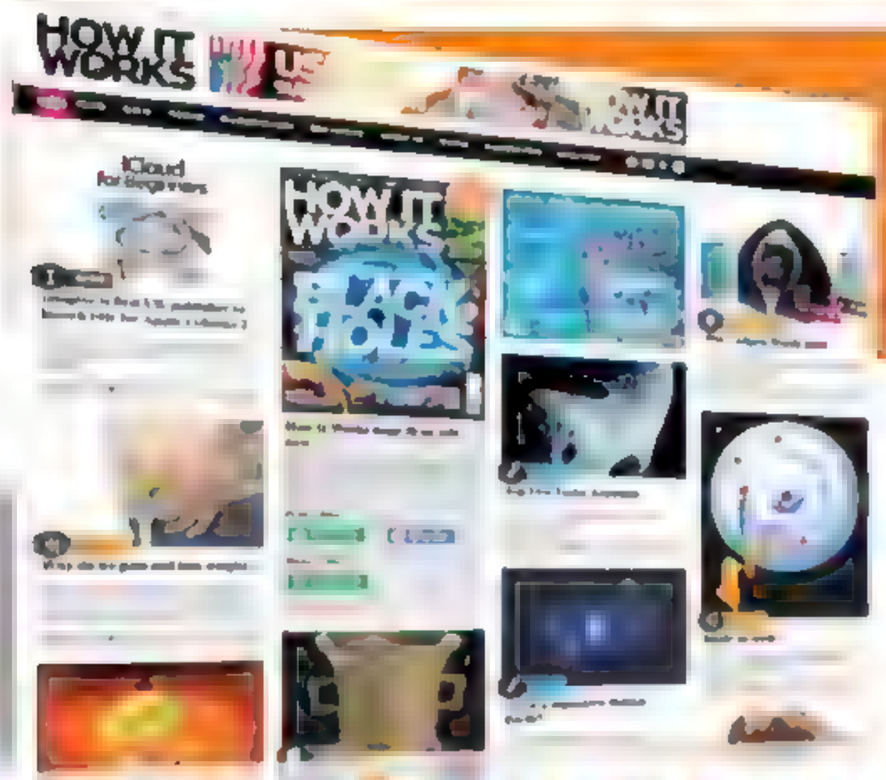

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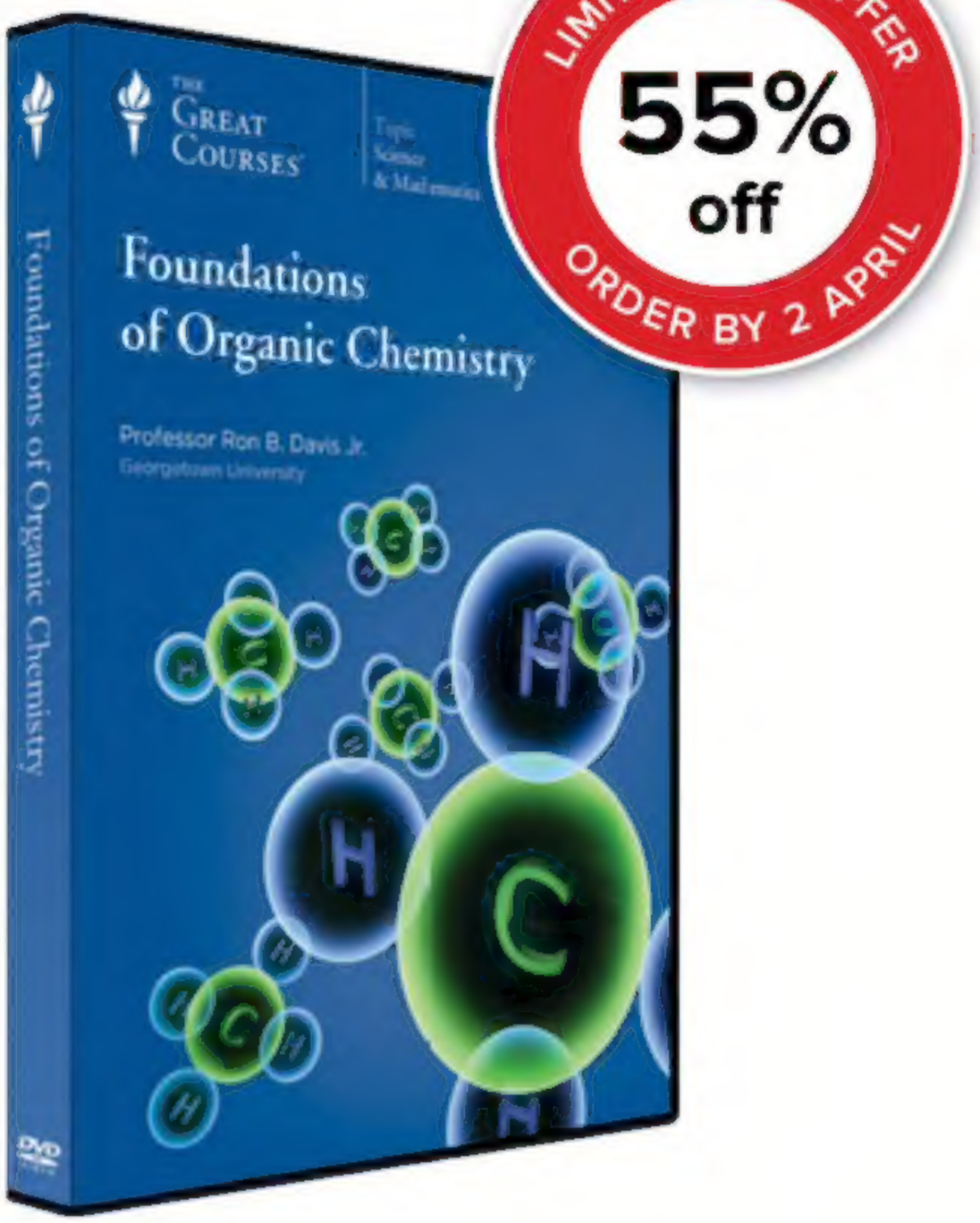

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